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EDITORS

JAMES D. AND EDWARD S. DANA.

ASSOCIATE EDITORS

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PROFESSORS H. A. NEWTON AND A. E. VERRILL, OF NEW HAVEN,

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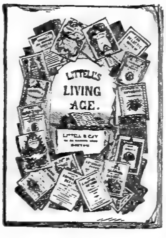

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AMERICAN JOURNAL OF SCIENCE

[THIRD SERIES.]

Art. I.—*On the Alternating Electric Arc between a Ball and Point;* by Edward L. Nichols.

[Contributions from the Physical Laboratory of Cornell University, No. 7.]

Part I.

(*From Experiments made by Messrs. W. K. Archbold, and G. L. Teeple.*)

The phenomenon which forms the subject of this paper, was first brought to my notice by Mr. E. G. Acheson, the result of whose unpublished observation, may be briefly stated as follows:

Two wires, which formed the terminals of the secondary coil of an alternating-current transformer, were brought nearly into contact. One wire was armed with a ball, the other with a point. When the distance was such as to admit of a discharge between the two, it was found that a galvanometer in shunt around the ball and point, indicated a considerable flow of continuous current.

This phenomenon has recently been subjected to investigation by Messrs. Archbold and Teeple. Their experiments, from which in great measure, the data used in the first part of this paper have been taken, are described at length in their Thesis in Electrical Engineering, which is now in the library of Cornell University.*

The apparatus used in the verification of Mr. Acheson's observation, consisted of a Ruhmkorff coil of moderate size, the

* The Effect of placing a Ball and Point in a High Potential Alternating Current Circuit, by W. K. Archbold and G. L. Teeple. Thesis in MS., Cornell University Library; 1889.

interrupter and condenser of which had been thrown out of circuit. The primary coil, as in all instruments of that type, consisted of a few turns of heavy wire, surrounding a core of iron wires. When this coil was supplied with current from a small alternating-current dynamo, making 14000 reversals a minute, and the terminals of the secondary coil were brought into position, a discharge of considerable brilliancy took place between them. To the unaided eye, the discharge appeared to be perfectly continuous, but the fact that it was really of an intermittent and periodic character, was indicated by the emission of a well defined musical note, which corresponded in frequency with the period of alternation of the dynamo.

The terminals of the secondary coil were subsequently connected with a brass ball, about one centimeter in diameter, and with a point consisting of a steel sewing needle. These were mounted horizontally in well insulated bearings, the center of the ball in line with the axis of the needle. The distance between the ball and the point of the needle was capable of adjustment by means of a micrometer screw. A mirror galvanometer of two thousand ohms, having in its outer circuit about one hundred thousand ohms, was shunted around the ball and point (in parallel circuit with the air space between them). When the induction coil was put into operation, the ball and point being too far apart to admit of a visible discharge, the galvanometer needle remained at zero, but when they were brought within striking distance, a large and constant deflection was produced. When the ball and point were interchanged, the deflection was reversed, its direction always being that which would have resulted from a current flowing from the ball to the point. Under the influence of the discharge, which was intensely luminous, the steel needle was fused at the point and rapidly wasted by oxidation, so that it became necessary to find some more refractory material.* It was finally supplanted by a pointed platinum wire, which although rendered highly incandescent withstood the temperature of the arc much better than steel had done.

The following quotation will serve to indicate the conclusions reached by the observers in the course of their preliminary experiments with the platinum point:

* The attempt to use carbon terminals, led to the following observation. "A carbon pencil substituted for the point, gave the same effect, but upon putting the carbon in place of the ball, it still acted as a 'point.' If two carbons were used the more pointed one acted as a 'point.'—It was observed that the end of the needle was fused into a ball by the heat of the arc, and would then act as a 'ball' to the smaller particles of carbon projecting from the end of the pencil.—Two brass balls brought together, caused a drifting of the galvanometer needle from one side to the other, according, it is to be presumed, as the discharge changed the nature of the two surfaces, so that minute points formed on one or the other." (Archbold and Teeple; Thesis, p. 3.)

"The behavior of the arc, as its length is increased, is very curious. As the point is withdrawn the arc forms and sings with an even tone, the pitch corresponding to the number of alternations. The point becomes of a dull red color while the galvanometer gives a small but quite steady deflection. As the arc is drawn out it sings louder and more harshly, the point becomes redder, while the galvanometer deflection increases and becomes very unsteady. At a certain critical length the following phenomena suddenly occur: the tone becomes smooth and even, the point brightens almost to a white heat, the intensity depending upon the strength of the current, while the galvanometer deflection becomes much greater and very steady. The explanation suggested, and which subsequent experiments seem to confirm, is as follows: At first the arc forms both ways, the rapid succession giving the tone. As the arc lengthens the arc still forms from ball to point, but is only intermittent (occasional) from point to ball, giving the unsteady tone and deflection. Finally the distance becomes too great for the arc to form from the point to the ball, while it still passes freely the other way, and the tone and deflection become steady."*

It was to the conditions existing in the circuit when the critical length of the arc, above mentioned, had been reached, that Messrs. Archbold and Teeple chiefly devoted themselves. The limits between which it was necessary to maintain the arc, were exceedingly narrow, a very slight extension of the striking distance beyond the critical point, resulting in total extinction of the discharge. Small changes in the speed of the machine were sufficient to throw the apparatus out of adjustment, and the arc, once ruptured, would not reappear spontaneously. It could be re-established, however, by the momentary introduction of a bit of metal between the ball and point, or even by the interposition of a candle flame. The complete stability of the discharge was finally secured by driving the dynamo by means of a motor, the latter being supplied from a storage battery.

The main portion of the investigation consisted in the determination of the periodic changes of electromotive force and current during a complete cycle, when no arc existed, and of the modifications introduced into the curves of potential and current by the discharge between ball and point. Throughout the entire series of measurements, the striking distance was greater than the critical value already defined, a condition the maintenance of which was secured by watching the indications of the galvanometer.

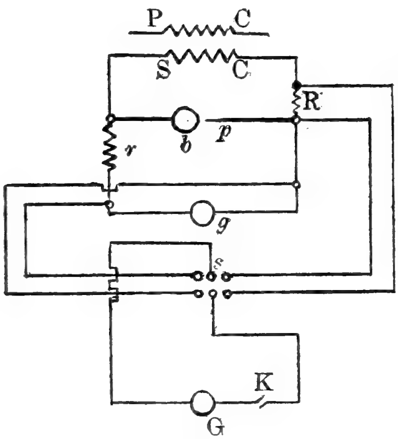
The instrument used in the measurement of electromotive force was a Thomson mirror galvanometer of ten thousand

* Archbold and Teeple; Thesis, p. 5.

ohms resistance. The galvanometer line was carried to the dynamo, where by means of an instantaneous contact device, the circuit was closed during an interval of exceedingly short duration, once in every revolution. The device consisted of a wooden disk, mounted upon the shaft of the machine. A single bar of brass, on the periphery of the disk, passed under a brush at every turn. This bar was connected metallically with a brass collar on the shaft, and a second brush, bearing upon the collar, completed the circuit. By thus closiug the line through the galvanometer, for an instant, once in a revolution, the electromotive force of the secondary circuit, at that particular point of the cycle for which the contacts were made, could be measured; and since the brush was adjustable through considerable range, the entire cycle could be explored.

The arrangement of the entire apparatus is shown in figure 1. PC and SC are the primary and secondary coils of the inductorium, p and b are respectively the point and ball. R is a non-inductive resistance, g the indicating galvanometer, in parallel with the ball and point, r a non-inductive resistance, s a switch by means of which the Thomson galvanometer could be shunted at will around R or g. K is the instantaneous contact device, and G is the Thomson galvanometer. When the Thomson galvanometer was shunted around R, which was placed in the main circuit leading from the induction coil, it served to indicate the current flowing in that circuit during that portion of the cycle for which contact was being made; when connected in shunt with the galvanometer g, it measured the fall of potential through the coils of the latter instrument. The function of the indicating galvanometer, during this part of the investigation, consisted in showing, by the size and direction of its deflection, whether the discharge between the ball and point continued to maintain its proper character.

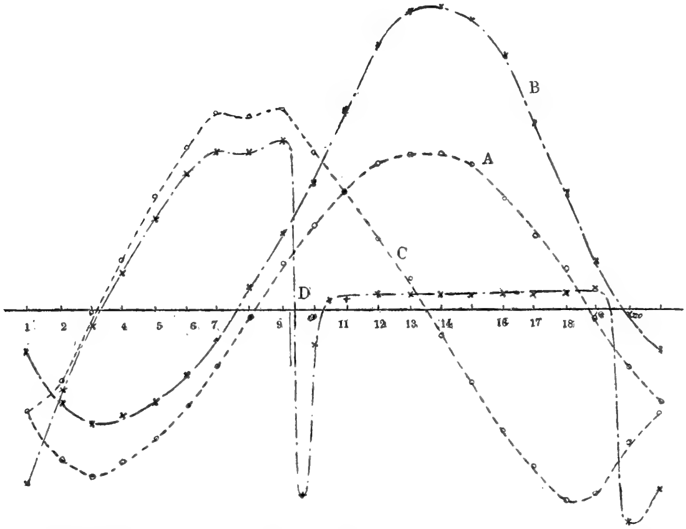
1.



The result of measurements throughout a complete cycle, both when the arc was formed and when it was extinguished, is shown in curves B and A, (figure 2). Curve A is with close approximation a curve of sines, and it indicates the usual fluctuations of current to be looked for in the secondary circuit of an alternating system. Curve B shows the current through-

out the cycle when the arc was playing. Abscissae represent portions of a complete cycle, the period being divided into twenty equal parts, ordinates the relative amounts of current through the resistance R, or the total current in the secondary circuit. Deflections, when the current flows from ball to point,

2.



are plotted above the base line. As may be seen from the curve B, the current flowing in the positive direction during each cycle was greatly in excess of that flowing in the negative direction, when the discharge was taking place between ball and point, whereas when no arc was formed, (curve A) the areas enclosed by the positive and negative branches of the curve were equal. Now there were two paths offered to the current, that through the galvanometer, g and the resistance r, which consisted of a column of copper-sulphate solution between copper poles (approximately 112000 ohms), on the one hand, and the parallel circuit between the ball and point on the other. The resistance of the latter path was infinite whenever the arc was interrupted, falling to finite values during each discharge. Increase of current through R indicates, therefore, the formation of the arc. Such increase is found to exist during the second half of each cycle, that is to say, during that interval in which the ball is positive; and it might be inferred from these curves alone that the discharge was an intermittent one taking place always from ball to point. Other curves, taken simultaneously with A and B, the Thomson galvanometer being shunted around the indicator galvanometer, lead to the same conclusion. The curves marked C and D (figure 2), show the

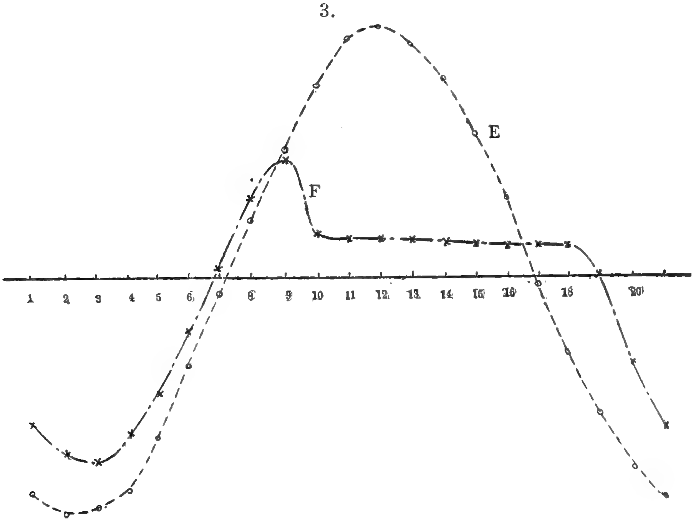
results obtained. It was thought that they would give the fluctuations in electromotive force between ball and point, corresponding in time to the current fluctuations in the resistance R. The indicating galvanometer, however, owing to the very rapid alternations to which the circuit was subjected, was found to possess such high self-induction as to materially influence the result. Strictly speaking, the curves C and D, therefore, give the periodic changes of electromotive force at the terminals of the indicator and not those occurring at the ball and point.

These curves are nevertheless of considerable interest. The curve C shows the character of the cycle when no arc was formed, and D, when the arc was in operation; C, like A, is approximately a curve of sines. The irregularity at its positive crest, which also appears in D, is probably due to the imperfect performance of the contact brush, and having no bearing upon the phenomena which the curves are intended to elucidate, may be disregarded. Since no current was passing between the ball and point when A and C were taken, they represent the fluctuations in successive portions of the same circuit. The lag, due to self-induction, however, is very marked, amounting to almost 90° of phase. Curve D, which shows the influence of the arc, is especially instructive. The potential rises during the first part of the cycle (ball positive); then follows a very sharp oscillation, occupying about one-twentieth of the entire period or 1/4600 of a second of time. The potential then reaches a small positive value which it maintains without fluctuation for at least four-tenths of a complete cycle, when it suddenly becomes strongly negative.

To obtain curves of electromotive force between ball and point directly, a non-inductive resistance was substituted for the indicating galvanometer and the measurements from which curves C and D had been drawn were repeated. Of the two curves thus determined, the one taken when the arc was not playing (E, figure 3), is a sine curve closely coinciding in phase with the simultaneous curve of current (A, figure 2). The corresponding curve F, which was taken while the discharge was passing between the ball and point, is in its essential features of the same character as curve D (figure 2). The interval of uniform positive potential is of the same length and it is coincident with the interval of excess of current which shows itself in the positive branch of curve B. It is noteworthy that this interval of uniform potential, which marks the duration of the arc, occupies in both cases the same portion of the cycle, (between scale-divisions 10 and 19, approximately), although there is otherwise a difference of phase, due to self-induction, amounting to at least four scale divisions. Curve

C for instance, reaches its maximum in the neighborhood of scale-division 8, curve E at scale-division 12. The exclusion of the coils of the indicating galvanometer from the circuit, reduced this difference of phase to a small quantity, and it suppressed altogether the remarkable oscillation of electromotive force (see curve D) which in all preceding experiments had introduced the formation of the arc.

3.



The results exhibited graphically in these six curves, afford abundant verification of the theory of the ball and point phenomenon, given in a previous paragraph; and they establish the fact that in the secondary circuit of a transformer, such as that made use of in these experiments, the striking distance from ball to point exceeds that from point to ball. It follows that whenever the space between the ball and point is less than the former and greater than the latter distance, discharge will occur only during that portion of each alternation for which the ball is positive, and that under such circumstances, a galvanometer placed in the circuit will show a constant deflection.

Complete corroboration of the foregoing conclusion, was obtained by studying the image of the arc in a revolving mirror. With a discharge of less than the critical length, the discharge was seen to consist of two distinct sets of sparks, all of the same duration but differing in color. Each alternate discharge was purple, the intermediate ones being of a greenish cast. The spark-images were everywhere equi-distant and their duration was about four times as great as the intervening intervals of darkness. The extension of the sparking distance beyond the critical point, resulted in the complete suppression of the

series of purple images, the intermediate ones remaining undisturbed in position, duration and appearance. The intervals of darkness were then estimated to occupy sixth-tenths of each cycle, the discharges, four-tenths; a ratio which corresponds with that of the duration of positive potential of the ball (as shown in curve) to the total length of a complete cycle.

The ball and point phenomenon is unquestionably very closely related to a class of effects with which students of static electricity have long been acquainted. One recalls, to begin with, Faraday's experiments with the Leyden jar; in which, of two paths, the spark invariably followed that involving passage from a positive ball to a negative point, in preference to another, through equal air-space, between a negative ball and a positive point.* Wiedemann and Rühlmann have since shown that between spherical electrodes which differ in diameter, the quantity of electricity necessary to produce a discharge is less when the larger ball is positive than when it is of negative charge,† and Macfarlane has measured the electromotive force which will produce a spark between a point and plate, and has found it to be greater when the point is positive than when it is negative.‡

In view of the experiments described in the present paper, it appears that what is true, in this particular, of the spark from the Leyden jar and the discharge of the Holtz machine, is true also of the alternating current arc.

Part II.

(From experiments made by Mr. F. C. Caldwell.)

After the completion of the experiments of Messrs. Archbold and Teeple, the study of the Ball and Point Phenomenon was taken up under the writer's direction by Mr. F. C. Caldwell; the chief purpose of the investigation being to test the applicability of the effect to alternate current measurement.§

Irregularities of action due to rapid changes in the surfaces of the point and ball, by corrosion and disintegration under the arc, finally caused the attempt to be abandoned, for the time being, but Mr. Caldwell in the course of his work, made a large number of observations of the discharge under various conditions. Many of these are of interest in this connection on account of the light which they throw upon the original experiments, and because of the lines of further research which they suggest.

* Faraday; Experimental Researches, § 1493.

† Wiedemann and Rühlmann: Annalen der Physik und Chemie, cxlv. See also Wiedemann; Elektricität, iv, p. 462.

‡ Alexander Macfarlane; Proceedings of the Royal Society of Edinburgh, vol. x, p. 555. 1879–80.

§ Frank Cary Caldwell: A study of the Alternating Arc between a Ball and Point. Thesis in MS. Library of Cornell University, 1890.

Mr. Caldwell's first step, after having repeated the preliminary experiments of Archbold and Teeple, and verified their statements, was to substitute a ball with a surface of platinum for the brass ball used by them. The new ball withstood the action of the arc no better than the old one had done. It soon became covered with a black deposit, the growth of which modified and vitiated the action of the apparatus. In experimenting with such a ball, the surface of which was still bright and new, and with a point of the same metal, it was noticed that within the critical distance, while the spark was passing in both directions, there appeared to be two distinct paths along which the discharge was taking place. One of these was nearly in the line from the point to the ball, normal to the surface of the latter. the other from the point in a direction approximately at 45° with the common axis of the pointed rod and ball. Upon increasing the distance until the discharge entered the "one way" stage, the longer and oblique path of flow vanished. In the revolving mirror the two classes of sparks were easily indentified. They were found to occur in alternation with each other, the spark which followed the normal path being that which passed from ball to point, the other that from point to ball. The images of the discharge from the point disappeared as soon as the critical distance was reached. In order to place the matter beyond all doubt, the times of the discharge which followed the normal path were determined by an ingenious method, quite independent of that used by the first observers, and it was found that the spark occurred always in that part of the cycle during which the ball was positive.

Mr. Caldwell's method of fixing the time of the discharge, briefly stated, was as follows. An adjustable contact device, similar to that used by Archbold and Teeple, was attached to the shaft of the dynamo. A wire from one pole of a large Holtz machine, driven by power, was carried to the neighborhood of the ball and point, where two platinum terminals, 1^{mm} apart were set up. The wire was connected with one of these and a line was carried from the other to the contact device. A wire from the latter to the remaining terminal of the Holtz machine completed the circuit. Whenever the brush made contact, a spark leaped between the platinum terminals, just described. By adjustment of the brush, the spark could be made to appear at any desired instant in the cycle of alternations of the dynamo. The platinum terminals were placed so that the image of the spark in the revolving mirror was seen side by side with that of the discharge between the ball and point, and the precise position in the cycle, occupied by the latter, was thus readily determined.

Closer study of the two paths of discharge showed that the oblique arc left the very apex of the point, swinging out later-

ally into its path; also that the normal arc on approaching the point, avoided the apex and entered the wire from the side, never passing in at the point itself.

From these observations it appears:

1. That the discharge from the ball (positive) leaves the latter in a direction normal to the surface, but that it enters the other terminal at some distance from the apex.

2. That the discharge from the point (positive) leaves the very apex of the latter, but is deflected into a course nearly 45° from the axis and reaches the ball obliquely at some point on its side.

Taking these observations into consideration, the explanation of the cessation of the discharge from the point at the critical distance and of the establishment of the "one way" arc, follows at once. The two paths of discharge differ in length and for a given electromotive force, the maximum striking distance is sooner reached in the case of the oblique than of the normal arc, so that the latter continues to pass at greater distances (of ball and point) than the former.

Further inspection of the images of the two arcs in the revolving mirror, revealed another curious fact. The mirror was set up with its axis of revolution parallel to the common axis of the ball and point. The image of an instantaneous spark following the line of the normal arc would therefore be a line parallel to the axis of the mirror. Since the duration of the discharge was nearly .001 seconds, this linear image was expanded into a broad rectangular band. The image of any oblique discharge would in general be an oblique parallelogram. The image of the discharge from point to ball, however, was not of that form. It appeared rather as a warped surface the form of which could be explained only by supposing that the discharge at first followed the normal path to the ball, and was gradually displaced as the cycle progressed, until it reached its extreme position at 45° to the axis, just before the rupture of the arc.

Definite results were obtained only while the platinum surface was new and bright. The region where the normal arc left the ball soon became tarnished and corroded and there was an increasing tendency on the part of the oblique arc to leave its own path and join the other.

When the ball was supplanted by a platinum wire, 1^{mm} in diameter, with rounded tip, the object being to force the two discharges into a common path, it was found that the arc from the point (positive) avoided the end of the wire altogether, and struck in upon the cylindrical surface beyond. When the end of this wire was surrounded by an insulated platinum ring which was connected with the terminal of the induction coil

by a separate wire,—the intention being if possible to separate the two phases of current and conduct them over different wires,—it was found that the arc from the point (positive) always entered the central wire, never being diverted to the ring, although the intervening air-space was less than a millimeter. The returning arc, however, would sometimes leave the ring and sometimes the wire, and a galvanometer placed in the circuit between the ring and the induction coil, showed a large deflection, such as would be caused by a flow of current towards the ring. This result seems to be in accordance with the conclusion reached from the inspection of the images in the revolving mirror: namely that the arc from the point always formed first along the shortest path. Deflection from that path in the case of the wire and ring, would probably be hindered by the insulating medium which intervened. When, finally, a cluster of points were opposed to the single point, it was found that the discharge from the latter was always along a single path, whereas the return arc from the cluster (positive) often followed several paths.

It had been noted by Messrs. Archbold and Teeple, that the platinum point used in their experiments, which was red hot while the arc was passing in both directions, became white hot during the "one way" stage. The heating effects at the surface of the brass ball were not discernible, but when Mr. Caldwell substituted a thin sheet of platinum for the ball, this became incandescent under the action of the arcs. The spot where the oblique arc (point positive) impinged upon the foil became white hot, while that at which the normal arc (ball positive) left the foil was barely red hot. In this respect then, the discharges act like the ordinary sparks of the influence machine or induction coil, which, as has been shown by Despretz, Poggendorf, Naccari and other observers, heat the negative electrode to a higher degree than the positive one. This action is in marked contradistinction to that of the continuous current arc, the positive terminal of which takes the higher temperature.

In this brief account of Mr. Caldwell's experiments, I have omitted to mention many of the observations recorded by him. He had occasion in the course of his investigation, to study the discharge under a variety of conditions, and found that when liquid surfaces (mercury or water) were used in place of the ball; also that when hydrogen, carbon-dioxide or illuminating gas were substituted for air, as a dielectric, the ball and point effect, more or less modified, could still be obtained. The investigation of these points, although it has already led to some results of significance, is as yet very incomplete.

Physical Laboratory of Cornell University:
September, 1890.

ART. II.—*Deformation of the Algonquin Beach, and Birth of Lake Huron;* by J. W. SPENCER.

FROM the ship's deck, my attention to the high terrace, which skirts the coast of Georgian Bay, was first attracted. But long before, fragments of this ancient shore-line were used by the Algonquin Indians, in the same manner as the Iroquois tribes had trailed over the "Ridge Roads" of Ontario and Erie. Mr. Sanford Flemming, C.E., described in 1853, some of the drift ridges at the head of Georgian Bay, and recognized certain high level beaches.* Later the Geological Survey of Canada measured the elevation of some of the raised terraces.† But those early investigators did not recognize either the extent of the beaches or their deformation from the water-level. No systematic explorations of the old shores were made until the summers of 1887 and 1888, when the writer, assisted by Professors W. W. Clendenin and W. J. Spillman surveyed portions of them. In the autumn of 1887, Mr. G. K. Gilbert visited some of the Canadian terraces. In August, 1888, I abruptly left the field and reported some results before the Cleveland meeting of the American Association for the Advancement of Science.‡ Some references to the Georgian Bay beaches were made in "The Iroquois Beach, etc.,"§ and later Mr. Gilbert generalized upon the history of the Upper Lakes, in an interesting paper entitled "The History of the Niagara River,"‖ wherein some of his raised shore-lines were taken from my survey, unpublished portions of which having been furnished to him.

Upon the Canadian side of the lakes, there are well preserved shore-lines, marking the same episodes, as those upon the American side, when all the lakes were covered by a common sheet of water (the Warren water). These raised beaches have been more or less surveyed, but they belong to an episode earlier than that recorded in the beach, which confined the waters to the Upper Lake basins not embracing that of Lake Erie. This beach, which skirted the head of Lake Huron, cutting off the waters from the Erie basin, is now submerged at its southern end, but it rises as a conspicuous feature in the

* Valley of Nottawasaga, Can., Jour. Toronto, vol. i, 1853.

† Geological Survey of Canada, 1863.

‡ "Notes on the Origin and History of the Great Lakes of North America," by J. W. Spencer. Proc. A. A. A. S., vol. xxxvii, 1888.

§ "The Iroquois Beach, a Chapter on the Geological History of Lake Ontario." Read before Phil. Soc. Wash., Jan. 1888, and Roy. Soc. Can., May, 1889. Proc. Phil. Soc. Wash., 1888. Trans. Roy. Soc. Can., 1889.

‖ Sixth Annual Report of the Commissioners of the State Reservation of Niagara for 1889.

topography of the country. I have named it after the Indians who, long ago, used it for a trail—the Algonquin Beach.* It forms the basis of this paper.

Between Lakes Huron, Ontario and Erie, at respective altitudes of 582, 573, and 247 feet above the sea, the land rises to 1709 feet. It shows water action to within 20 feet of its summit. From the highest ridges or plains, the land falls away towards the lakes, sometimes gradually, but often by abrupt steps, especially upon the northeastern side. Over this peninsula, there are many ridges of drift. Exclusive of the ridges, the general surface of the country is composed of fine stony till, or of modified drift,—the product of wave action upon the stony clay, the result of which has been the formation of beach ridges of sand and gravel, separated by plains of silt or clay soil. In many cases, these floors slope so gently as to appear level, and from two to five or six miles may intervene between successive beaches, whose altitudes do not differ by more than 50 or 60 feet. The silt on these plains is that which was washed out into the deeper water, by the assorting action of the waves that were building sand or gravel beaches in front of their coast lines, composed of the older stony clay. In such cases, the lithological recognition is striking. Upon surveying, the beaches are all found to rise in altitude toward the north and east, with a slightly increasing divergence between the ridges in the same direction, for the differential uplift has always been greater toward the northeast, than in the opposite direction.

The methods of investigation have been similar to those pursued in the survey of the Iroquois Beach. Boulder pavements are rather more important features of the Algonquin Beach than of the Iroquois. About the head of Georgian Bay the country is sandy. East of Georgian Bay, there is the same kind of broken wilderness as that among the Archæan rocks of the Adirondack Mountains of New York, with more or less stony sand in place of stony clay.

The waves of the lake are encroaching upon the eastern coast of Huron, and consequently modern beach-making is not a characteristic feature, except in proximity to the mouths of some streams or in sheltered places, where terraces or bars are constructed. The encroachments of the lake upon the land have washed away, in many places, the bluffs upon which the Algonquin Beach rests. But a sufficient number of fragments remain, for its identification, especially as the position relative to its elevation, compared with the next higher shore-lines, which are well marked by beaches, is known.

* The name was first printed in Proc. A. A. A. S., p. 199, 1888.

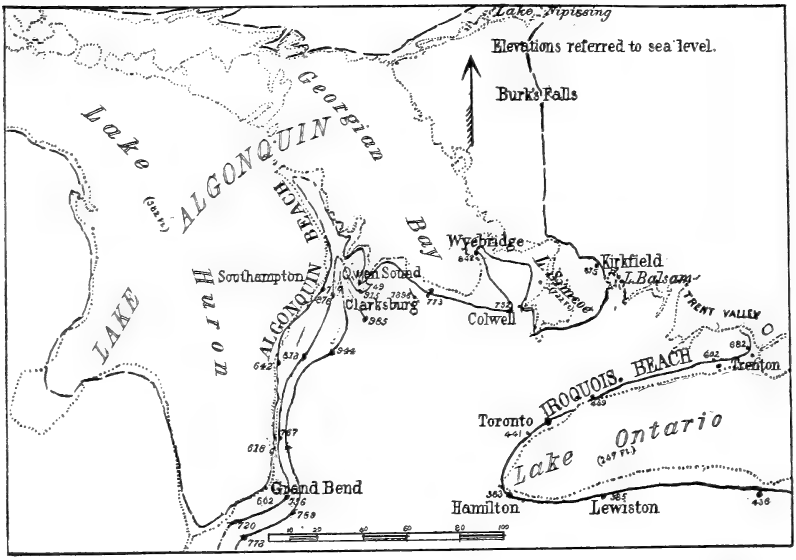


Fig. 1.—Map showing the Algonquin Beach about the eastern portion of Algonquin Lake. Other beaches are also shown.

The following table gives the levelled elevations of salient points along the Algonquin Beach, at or near the places mentioned:

	Feet above the Sea.	
Surface of Lake Huron	582	(U. S. Lake Survey.)
Beach at one or two miles lakeward of modern outlet of Lake Huron, calculated	562	(Spencer.)
Grand Bend (of Au Sable River)	602	"
Wilson's (14 miles northward, terrace at 608 feet, calculated)	618	"
Eighteen Mile Creek (terrace 637 feet, calculated)	647	(Barometer.)
Southampton (back of which a sand dune rises 13 feet higher)	714	(Spencer.)
Thence the beach skirts Indian Peninsula, and at Owen Sound	749	"
Clarksburg	773	"
Collingwood, 4 miles west of	767	"
Colwell	752	"
Elmsvale	802	"
Wyebridge, east of	842	"
Orillia, about	800	(Barometer.)
Thence the beach descends and swings around Lake Simcoe and again rises at Kirkfield	875	(Spencer.)
Burk's Falls (+ or −) (?)	1171	(N. W. & N. Ry.)

Beyond Kirkfield, the survey was not carried, but from the topography of the country and from the fragments of the beaches, the position of the Algonquin Beach is approximately that of the broken line on the map. The gravel ridge at Burk's Falls is probably part of the beach, as the mean rate of northern rise would represent its position near this point.

For comparison with the Algonquin Beach, the positions and the elevations of the two next higher beaches, east of Lake Huron are given on the map, and the tables of elevations are here added. Of next beach, at or near:

	Feet above the Sea.	
Forest	720	(Spencer.)
Parkhill, east of	736	"
Bayfield, east of	767	"
Ripley	813	"
Walkerton (terrace)	825	"
Paisley (terrace)	860	"
Burgoyne (east of Southampton)	876	"
Rockford, north of	915	"
North coast of Lake Simcoe (probably that) on the insular ridge north of Barrie	910	"

Of the second beach above the Algonquin, at or near:

Watford	773	"
Ailsa Craig	789	
Varna	845	(+)
Walkerton	944	
Chatsworth	985	

A still higher beach has been surveyed for many miles, and several fragments of even more elevated shores are now well identified. Some of these upper beaches have been traced over long distances, and have been found resting upon the land north of Lake Erie, and even extending to the high country between Lake Ontario and Georgian Bay.

From the figures recorded in the three tables, it will be found that the mean rate of warping in the Algonquin Beach, from the southern end of the lake to near Southampton, is 1·33 feet per mile; of the next beach, between Parkhill and Burgoyne, 1·5 feet; and of the higher beach, between Watford and Walkerton, 1·71 feet. These rates of differential uplift are reduced at their more southern extensions, but increased to two feet, or somewhat more, at the more northern.

After skirting the Indian Peninsula, the position of the Algonquin Beach surrounding the head of Georgian Bay is such that it can be triangulated, and hence the average amount of uplift, as well as its direction can be obtained. Accordingly, it is found that the uplift upon the more south-

western portion of the beach, at the head of the bay, is about 3 feet per mile, in a direction of N. 20° E., with an eastern equivalent of about one foot per mile. The uplift increases so that east of Georgian Bay the mean rise is 4·1 feet per mile in a direction of N. 25° E., with the eastern equivalent of 1·7 feet per mile.

At Grand Bend, the beach rests upon a fine stony drift clay—the latest deposit of till in that region—which is charged with numerous scratched stones. It is also indistinctly stratified. The same holds true at Wilson's and other places. About Georgian Bay, it also rests upon the upper till. In short, the waves, which formed the beach, have commonly removed the silt deposits that covered the floor of the lake, during the earlier episodes of the higher beaches, and cut into the underlying drift deposits during the Algonquin episode, before the beach structure was laid down. In many places, especially about Georgian Bay, the boulder-pavements are well developed, especially between the different ridges of the Algonquin Beach, for it is often broken up into a series of prominent ridgelets, the lowest being, where developed, as much as 28 feet below the upper.

There are several beaches about Georgian Bay, at lower altitudes than the Algonquin, but these rise less rapidly toward the northeast than the greater named beach. At Clarksburg, there is a beach at 81 feet above the lake, and terraces at 62 and 45 feet, besides a numerous series of beaches extending from 28 feet down to the water level. Near Wyebridge, the more conspicuous terraces are at about 183, 73, 55 and 11 feet above the lake; and there are numerous fainter shore-lines. These all show that the time of the subsiding of the waters was marked by numerous pauses.

Between Kirkville and Balsam Lake, there is a depression a few feet below the level of the upper part of the Algonquin Beach. But of this later.

No animal life has been found in the beach itself. But in a terrace, adjacent to the Saugeen River (bridge east of Southampton), where there is an embayment of the Algonquin Beach, there is a bed of fresh-water shells, discovered by Mr. Spillman. This is at an altitude of 90 feet above the lake, or over 40 below the beach. This deposit may have been on the floor of the lake during the Algonquin episode, or it may belong to a lower water-level. The river has now cut down its bed far below this level. At the head of Georgian Bay, fresh water shells have been found up to 78 feet.*

There are several depressions across the Laurentian Mountains, between Lake Huron and Hudson Bay which do not

* Geology of Canada, 1863.

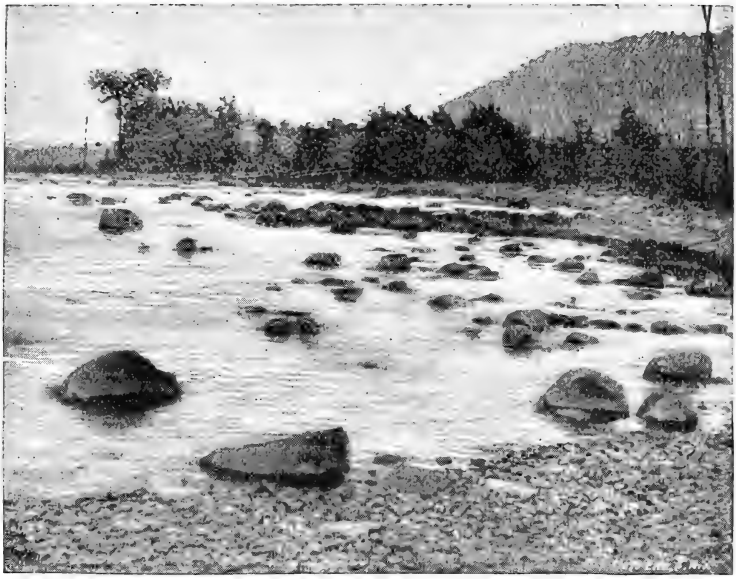


FIG 2.—MODERN BOULDER PAVEMENT ON GEORGIAN BAY, NEAR THE END OF BLUE MOUNTAINS OF COLLINGWOOD, ONT.

FIG. 3.—ANCIENT BOULDER PAVEMENT OF ALGONQUIN BEACH. (whose crest rises 187 feet above Georgian Bay) upon the N. E. side of Blue Mountains of Collingwood, Ont.

rise much more than 900 feet above the sea. But towards the northeast, the altitude of the land is everywhere high, except along the depression in which Lake Nipissing lies. The barrier there descends to 707 feet above the sea. Beaches and shore lines are known to exist upon the land north of the lakes, and I have seen such upon Manitoulin and Mackinac Island. But they have not been directly connected with the more southern beaches. Consequently, all deductions, in the study of the lake involving that district, must be somewhat provisional. From the character of the terrestrial rise increasing towards the east, it is probable that there are no depressions north of Lake Huron, lower than the plain of the Algonquin Beach. This beach (by calculation from the mean rate of rise) should be found in the vicinity of Lake Nipissing, at from 600 to 700 feet above that depression.

Combining the Canadian series of beaches about the upper lakes with corresponding series on the southern side of the lakes (my survey of those in Michigan being still unpublished), I find that there has been a differential elevation, since the Algonquin episode, between the southern end of Lake Michigan and the vicinity of Grand Bend, on Lake Huron, amounting to about 290 feet. Hence, we know that the Algonquin plain was down to a level, at least, of less than 300 feet above the sea. By a triple series of calculations, the Algonquin plain is found to have had a position somewhat less than 300 feet above the Iroquois plain. The Algonquin water filled the Huron basin to within a mile or two of its southern end, where the beach is now submerged to about 20 feet, (calculated). Hence, the waters did not flow by the modern St. Clair River to the south. At this time a considerable area of the southern end of Lake Michigan was laid dry, as the beach bounding the Algonquin water should now be submerged to 290 feet below the waters of that modern lake. But the northern part of the Michigan and Huron basins was filled to an elevation far above their present surface, as the basins had not yet received that great tilting which partly overflowed their southern margins and lowered their surfaces toward the north.

There is a well-marked terrace and beach deposit on Mackinac Island, at about 190 feet above the lake. This is nearly in the line of strike, or line along which there is no differential elevation, of the lowest part of Algonquin Beach about Georgian Bay. This old shore line, on the island, is better developed than any of the Huron Beaches, situated elsewhere, except the Algonquin. From its position, there seems no reason to doubt that the waters of Algonquin lake stood at that elevation in the strait between the Michigan and Huron basins. Accordingly, tilting in the Michigan basins has amounted,

since the Algonquin episode, to about 430 feet in 300 miles, or a little more. This approximation is close upon the mean rate of uplift measured east of Lake Huron. Parenthetically, it may be added that President Chamberlain found clays upon the western side of the lake which represent a differential uplift of 400 feet (although they belong to an older episode), which were in part involved in the earlier Pleistocene movements.

The Algonquin water also covered most of Lake Superior, probably to within a short distance of its southwestern end, as that basin is so deep; yet the waters must have been very much shallowed. Indeed, the recent backing of the waters towards the head of Lake Superior is apparent in the open bays behind the bars, which cut off Fond du Lac, at Duluth. The area of the Algonquin Lake or Water may be seen from what has been written, to have been vastly greater than now, filling the upper lake basins, nearly to their extreme margins, and overflowing the land northeast of Georgian Bay, as shown on the map. On Mackinac Island and adjacent portions of the mainland, there are several shore lines lower than that assigned to the Algonquin plain and of inferior importance.

In the early history of the Algonquin water, there was an overflow by way of Balsam Lake and the Trent valley. My first impressions of the importance of this outlet were overdrawn in the preliminary communication* of observations from the field, before all of the relations had been explored. At first I attached as much importance to the Balsam outlet of the Algonquin basin as Mr. Gilbert did to his Mohawk outlet of the Iroquois basin. As both are too shallow, the demands are satisfied in neither case. Only at its highest level did the Algonquin Lake overflow into Balsam Lake. Even the overflow was sluggish, permitting of the formation of beaches about the outlet. Before Algonquin water sank to the level of its lower beaches, its discharge was by a channel below Balsam outlet. The occurrence of an overflow in this last direction, is only one of the coincidences, as in other cases, in the growth of the lake. The outlet of the Algonquin Basin, by way of Lake Nipissing and the Ottawa valley, was through a depression, which now rises to 707 feet above tide. This trough has now an absolute depression of 168 feet below the Algonquin Beach at Kirkfield. But the altitude of the beach, in the region of the old Nipissing outlet, is estimated at 600–700 feet above its floor. In short the outlet was a broad strait leading into the Iroquois Basin, or like the modern connections between Lake Michigan, Lake Huron, and Georgian Bay, unless the basin were closed by a dam, and that of ice. The

* Proc. Am. Assoc. Adv. Sci., 1888, p. 197.

case is not settled so easily as that of the Ontario basin, for we have not yet the instrumentally measurable proof that the Algonquin plain was lower than 300 feet above the sea, although it probably was, and against which probabiltiy there is not the slightest evidence, for we do not know what was the initial plain of upward movement. Without applying the objections made to an ice dam closing the Ontario basin during the Iroquois episode, let us examine some conditions of the Algonquin basin.

The Algonquin plain stood at an elevation of about 300 feet above the sea, when the lower Iroquois Beach commenced its growth. Were its waters held up to that altitude by an ice dam, or had they shrunken to the lower level (which, however, would not have dismembered the upper lake) and were they connected with Lake Iroquois by a strait 300 or 400 feet deep, like the modern outlet of Lake Michigan? Up to this time, there had not been any warping to separate the lake basins, for the greater part of the barriers has been uplifted since the episodes of the Algonquin and Iroquois Beaches. I have shown that the greater proportion of the differential movement, even in the higher beaches about Lake Erie has been since the Iroquois episode.* In the earlier part of this paper, it has also been shown that most of the warping of the beaches, east of Lake Huron, has been since the Algonquin episode. Now these higher beaches are identical with those south of Lake Erie, whose movement have been compared with those of the Iroquois Beach. Hence, it is not difficult to understand that the unequal uplift of both the Algonquin and Iroquois plains has been nearly synchronous, since the completion of the latter beach. I speak only of the differential movements that have deformed the old water levels, and not of the absolute rise, which lifted the Algonquin plain above the Iroquois, unless the waters which made the former beach were retained at the higher altitude, for long ages, by an ice dam.

At most, no ice barrier could have longer blocked the Nipissing outlet than the episode of the lowering of the waters, 300 feet, to the level of the Iroquois Beach, for at that time, all glaciers had shrunken back beyond the Ontario basin, and the two basins were connected by the deep Nipissing Strait. And of such a dam we have not proof, or even probability, to even as great an extent as in the case of a hypothetical Iroquois dam. With the continued regional uplift, the waters of Algonquin Lake were further lowered, as is shown by the numerous beaches, until the lake was dismembered, and *Superior, Michigan, Huron and Georgia had their birth* and drained through

* "Deformation of the Iroquois Beach," etc. This Journal, vol. xl, page 443, 1890.

the last, at the level of the Nipissing outlet, only by a river flowing into the valley of the Ottawa.*

As we ascend to the elevation of the higher beaches, the question of glacial dams becomes more difficult, for we must assume them to have been hundreds of miles long and at enormous altitude, damming up bodies of water which had the proportions of inland seas. Such, I do not here propose to construct or dissipate, but I am compelled to assume the initial plain of the Algonquin Beach at sea-level, irrespective of glaciers which may then have been moving into the St. Lawrence valley, and obstructing open communication with the sea, but not damming the waters at high levels. There is as much evidence of submergence in these deserted beaches as there is in Professor Shaler's beaches † up to 1500 feet, on Mt. Desert Island, without the intervention of dams, or of Mr. McGee's Columbian formation‡ which I have seen in Alabama, at altitudes of about 700 feet without the support of dams. Indeed, there is additional evidence, for crustaceans of marine species have so adapted themselves as to still live in the depths of Lake Superior,§ as also maritime plants upon its shores.‖

As Algonquin water received so much fresh water, the marine conditions, indicated above, were modified, so that almost immediately after, if not during the formation of the Algonquin Beach, the waters became sweet, as is shown by shells referred to above. With the continued emergence and northeastward warping of the continent, a rocky barrier across the Nipissing outlet was raised which eventually caused the waters of Georgian, Huron, and Michigan Lakes to unite and overflow the southern extension of the lower beaches. Finally, this warping, as before pointed out,¶ so tilted the basins of the lakes that the waters overflowed the southern rim of the Huron basin, and established the modern drainage of the upper Lakes by way of Lake Erie. Not until this event did the lakes assume their present form.

* See History of the Niagara River, by G. K. Gilbert.

† Geology of Mount Desert, by N. S. Shaler. Eighth Annual Report of U. S. Geological Survey, 1888.

‡ By W. J. McGee. Bull. Geol. Soc. Am., vol. i, 1889.

§ "On the Deep-Water Fauna of Lake Michigan." (Stimpson) Am. Nat., vol. iv, p. 403, 1870; also "The Crustacea of the Fresh Waters of the United States." (Sidney I. Smith). Rep. Fish Commissioner, 1872–3, p. 643.

‖ "The Distribution of Maritime Plants in North America." (C. H. Hitchcock). Proc. A. A. A. S, 1870.

¶ Notes upon the Origin and History of the Great Lakes of North America, Proc. A. A. A. S., vol. xxxvii, p. 197, 1888.

ART. III.—*The Decimal System of Measures of the Seventeenth Century ;* by Professor J. HOWARD GORE, B.S., Ph.D.

JUNE 17, 1799, was a remarkable day in the history of the "Comission des Poids et Measures." After nearly nine years labor an arc of the meridian had been measured, the earth's quadrant had been computed, and now a bar whose length was one-ten-millionth of this quadrant, was formally presented to the two "conseils du corps Législatif." It is quite natural that the members of this commission should rejoice over the conclusion of their work, a work which readily sustained the closest scrutiny, and withstood the severest criticism, nor is it surprising that their spokesman should say: "to employ as a fundamental unit of all measures a type taken from Nature herself, a type as unalterable as the globe which we inhabit, to propose a metric system all of whose parts are intimately interdependent, and whose multiples and subdivisions follow a natural progression, simple, easy to comprehend, and always uniform, is certainly an idea, beautiful, grand, sublime, worthy of the brilliant century in which we live." In the detailed account of operations which follow, there is interspersed a large amount of praise for the participants—from Talleyrand, who laid the proposition before the Assembly on May 8, 1790, down to the laborers who carried in the prototype, on this august occasion. But one looks in vain for a mention even of the name of the humble, modest priest who deserves the credit of first proposing "a type taken from nature herself, as unalterable as the globe which we inhabit." This priest was Gabriel Mouton, of the collegiate church of St. Paul of Lyons. We shall see how well-known he was to his contemporaries and successors, and whether his system was borrowed by the advocates of the metric system, or was a subsequent independent discovery, after we shall have given an outline of his system.

	Milliare.	Stadia.	Funiculi.	Virgæ.	Virgulæ.	Digiti.	Grama.	Puncta.
Milliare	1	0	0	0	0	0	0	0
Stadium		1	0	0	0	0	0	0
Funiculus			1	0	0	0	0	0
Virga				1	0	0	0	0
Virgula					1	0	0	0
Digitus						1	0	0
Granum							1	0
Punctum								1

This scheme derived its unit from a *minute* of the arc of the largest circle that can be drawn around the world. A minute of arc was called a *milliare;* one-tenth of a milliare was to be called a *stadium;* one-tenth of a stadium, a *funiculus;* one-tenth of a funiculus, a *virga;* one-tenth of a virga, a *virgula;* one-tenth of a virgula, a *digitus;* one-tenth of a digitus, a *granum;* one-tenth of a granum, a *punctum;* as is conveniently exhibited in the following diagram:

If the above terms appear inconvenient to any one, the following were given so that one could take one's choice: Milliare, centuria, decuria, virga, virgula, decima, centesima, millesima. If we now take the accepted value for the quadrant in English measure, the various units will have these lengths in inches:

Milliare	72908·
Centuria	7290·8
Decuria	729·08
Virga	72·908
Virgula	7·2908
Decima	·7290
Centesima	·0729
Millesima	·0072

There were to be two units, the virga for large measures, and virgula for shorter ones—the former, about six feet, is most convenient for measuring those distances now expressed in yards, or meters, while the latter would be suited to those quantities now expressed as fractional parts of a foot, or feet. Those who use the metric system find that the meter is rather long for the latter class of quantities, nor is it convenient to use decimeter, and the jump to centimeter is too great, while for the first named measures the meter is too short. If these views be correct, Mouton's duplex units virga, and virgula are preferable to the meter.

Just when this scheme was proposed is not known, but it was prior to 1665, as some observations in connection with the fixing of his standards were made on the 8th of March of that year. Geodesy had not reached at this time a stage where its results could suggest their application to metrology; in fact only two determinations of the length of terrestrial degrees had been made, those of Snell and Riccioli, in 1617 and 1665 respectively. Not enough was then known of methods to enable one to judge as to the accuracy of either of these determinations, but Mouton says: Of all the observations I know of, ancient as well as modern, those of John Baptist Riccioli, which are described in the fifth geometrical book of the revised geography please me most, both on account of their wonderful harmony and the singular diligence which the above-mentioned

author has exhibited in treating of them, and also the industry and labor of twelve years, which he bore with an unwearied mind, for the sake of the truth that was to be attained. Indeed, I have such confidence in these observations, that I would regard my own, if I had any, as inferior to them; but hitherto I have been unable to accomplish anything in this subject, although I am very fond of such things. Mouton's estimate of Riccioli's work was far above its deserts, perhaps owing to the fact that they were friends and closely united by religious ties. An examination of Riccioli's arc measurement shows that his base was very short, that only two angles of each triangle were observed, that many of the angles were small, that some were determined indirectly as sums or differences of other angles, that no corrections were made for refraction and that some distances were estimated from meandered lines. Hence we are prepared for an erroneous result—62,650 toises for a degree. Snell's result was far superior, but was most likely unknown to Mouton—as the work published in Leyden would with difficulty reach Lyons, nor did the discussions of Munschenbroek and Cassini appear until many years after. So all the observations, ancient as well as modern, were represented on the modern side by those of Riccioli, Fernel and probably Norwood, as Picard had not at this time begun his labors. Our Metrologist went still further, not being satisfied with merely suggesting a system, he gave the length of his unit in terms of other measures. Riccioli gave his degree length in terms of the Bologna foot, and also in terms of the old Roman foot. This furnished Mouton a check as he had the ratio of the French foot to both; the two reductions were harmonious, justifying his belief that we cannot be ignorant of the true length of the virga and the virgula, which in comparison with the other geometrical measures are easily attained; and for the sake of this length, "we must test and observe many things, that will be not a little useful for the preservation of these measures." In reading this, one would hardly imagine that the pendulum principle discovered only a few years before this—though not published until eight years later, was referred to, and that Mouton had in mind the second's pendulum as the best means of preserving and transmitting his standard; yet this was the case, as we shall see from what follows: "A geometrical virgula is exactly equal to a pendulum which makes 2959·2 single vibrations in half an hour, as we shall show by means of many experiments, used for this purpose, through which we endeavor to show the length of the virga and virgula, a thing to be known by all others wishing to obtain it.

"In making use of the following and similar experiments, a very exact knowledge is required of the time that has elapsed. In order to obtain this knowledge more readily we must have recourse to the clocks of Christian Huygens, which are constructed with hanging weights. This Huygens was a remarkable man, of great learning, and one to whom posterity will always be largely indebted for his great assistance in mathematics. His clocks excel all others and correspond so nearly to the daily revolution of the sun that nothing more accurate can be hoped for. The fewer the wheels that are required in their construction, the more regular is their motion, but it is necessary for them to show the seconds as well as the minutes and hours, or if they fail to do this, we must count the single vibrations of a pendulum which will take place in a certain specified time. The motion of the pendulum, or the definite number of vibrations in a given time, when all outside resistance has been excluded, depends entirely upon its length, and if this varies very little, it must necessarily either increase or diminish the number of vibrations, and we prove by a common experiment that the squares of the numbers of vibrations of two pendulums that are equal in all respects except that of length, and vibrating the same length of time, are to each other in a reciprocal ratio as the lengths of the pendulums; and conversely the lengths of the pendulums are to each other in a reciprocal ratio, as the squares of the vibrations. I made a pendulum with a hemp string and an iron ball I divided the length—which may be anything—of the pendulum into 6772 equal parts, by means of an arbitrary division, for any number will do for the purpose, and nothing else is necessary except that the parts be very small. The length of the pendulum is the distance from the center of the sphere to the end of the thread. In this case the diameter of the ball was 160 of these parts, and the thickness of the thread almost 2 of the same. Having compared the aforesaid pendulum with the virga, the length of the virga was found to consist of 5397 of these parts. This being duly determined, I began counting the single vibrations of the pendulum, using two clocks with very fine weights, indicating seconds as well as minutes and hours. On the 8th of March, 1665, I counted different numbers of vibrations, corresponding to different periods of time, and repeated the operation about ten times. Upon the agreement of all these, the number of single vibrations in the space of half an hour was found to be 1117½, which, applying the proportion already given, would show that a pendulum, the length of which is equal to a virga, makes 1251·8 single vibrations in half an hour." Subsequent observations gave for this quantity 1252, 1252·1, 1252·1, using pendulums of different

lengths and with balls of various sizes. The indiscriminate mean of these four series is $1252 \pm 0{\cdot}047$, a result which reflects great credit upon the observer. On the margin of a page is given the length of a virgula, with the naive confession that it is not given with such accuracy that we can take copies from it as if it were the standard—a remark made unnecessary by the careless trimming of the bookbinder.

The facts here established are: 1. Mouton devised a system of measure, arranged upon the scale of tens. 2. He derived his unit from the length of a minute of the terrestrial arc. 3. He showed how this unit could be expressed in terms of the seconds pendulum. It is now added, that this is the earliest decimal system proposed, that the French Academicians knew of this system, took from it its best features, and never gave credit where credit was due. Chronology shows it to be the earliest. As already stated, the two units, virga and virgula are more convenient lengths than the yard and foot, meter and decimeter; and so far as names are concerned, *decuria*, by tens, is as good as dekameter, while *decima*, the tenth part is better than decimeter. Again, the virga is an exact part of a minute, and is therefore an exact division of degree, quadrant and circumference, while the meter has *nine* degrees as its smallest exact multiple.

The only remaining point to be considered is: to what extent was Mouton known to his contemporaries and successors? As to the former it is impossible to even surmise.

His system forms pages 427–448 of his treatise "Observationes Diametrorum Solis et Lunæ . . . Una cum Nova Mensurarum Geometricarum Idea." Lugduni [Lyons] 1670. This small quarto was published with the "approval and permission of superiors," who, judging from the names appearing on the page which contains these approvals and consent, are the chairman of the Faculty of Paris, a Carmelite monk who announces that the book is orthodox, and a *Procureur du Roy*. This would give the book at least three readings before it was printed, and by men of such ability that they would appreciate the system proposed and discuss it with others.

Picard saw the book soon after its publication, nor did he soon forget it. This is shown in a report, published in vol. vii of the Memoirs of the Paris Acad., 1729, of observations made in 1672, 1673, and 1674. Picard, elated over the success which he had achieved in his geodetic work, sought new glory in making accurate astronomic observations at some of the principal cities of France. One of these places was Lyons, and while discussing his observations made when there he says: M. Mouton in his discussion of a universal measure, said that at Lyons a simple pendulum whose length was equal to a Paris

foot—a length given him by Auzout—made 2140·4 vibrations in half an hour, from which he concluded that the length of the seconds pendulum would be 36 inches 6·3 lines. That caused me to examine the matter very carefully while I was at Lyons, using for this purpose a large clock such as I had used elsewhere; and after all, I remained convinced that the true length of the second's pendulum at Lyons was 36 inches, 8·5 lines.

This application of the pendulum evidently pleased Picard, as in the same report he adds: if one had found the length of a seconds pendulum expressed in the usual measures of each country, one could know the relations of these measures as if they had been directly compared with one another,—besides this, one could detect at any time in the future a change in their lengths. These universal measures suppose that a change of locality produce no appreciable variation in the length of the pendulum; it is true that experiments have been made at London, Lyons, and Bologna, which seem to show that the pendulum shortens as the equator is approached, . . . but we are not sufficiently informed as to the accuracy of these observations to deduce any conclusions from them. Picard did not care to endorse the possibility of this shortening of the pendulum, it would have tended to corroborate the oblate spheroid hypothesis, which at this time was not at all popular at Paris. In 1733, Mouton sent to the Academy at Paris, a copy of the trigonometric tables which he had computed. In the note of acknowledgment, he is referred to as very well known by his work on the diameters of the sun and moon, and is called "habile dans les mathématiques."

As late as 1776 de la Condamine says: M. Mouton, priest at Lyons, was the first, whom I know, to propose a unit deducible from the pendulum; this was in 1670. He adds that it was proposed by Mouton in 1668 (it should be 1665), adopted by Picard in 1672, and by Huygens in the same year.

Cassini, in 1757, refers to Mouton as one whom we know only as a priest and master of the choir at the collegiate church of St. Paul. Perhaps this is simply to prevent people from supposing that his own scheme was not taken partly or wholly from Mouton. He proposed to take one six-millionth part of a minute of a terrestrial arc and call it a foot. He also suggested that the unit be a toise, 60,000 toises being contained in a degree. This was simply taking one-thousandth of a minute, which was Mouton's identical plan.

Thus it is seen that Mouton's idea was never lost sight of. He was quoted often enough, and by such men as to keep his views from being forgotten, but when we come to that monumental work which recounts the incentives, beginnings, meth-

ods and results of the commission which deduced a standard of length, following a scheme proposed a hundred and thirty years before, and using a nomenclature too much like the former to be original, we seek in vain for a proper recognition of obligation and find in a few lines a mutilated account of Mouton's scheme, while he barely escapes condemnation in some words of faint praise from those who had thought of a universal measure. It is confidently believed that he who was known only as a priest and chorister was the originator of the decimal system of measures based upon geodetic data, and the brilliant century which deserves credit for the inception of a system which now promises to become universal was not the EIGHTEENTH but the SEVENTEENTH.

ART. IV.—*On the Clinton Oolitic Iron Ores;* by AUG. F. FOERSTE.

IN the Clinton Group districts of the Alleghany Mountains, the Clinton iron ores are often of the variety known as *Oolitic.* In making sections of these ores I discovered that the oolitic grains characterizing them frequently show the structure of bryozoans, and more evidently fragmental remains of the same. The grains, although rounded, have by no means the spherical character usually found in oolitic *concretions*, such for instance as occur in the so-called green sands of Cretaceous and Miocene age in this country. They evidently vary in size and shape with the character of the species from which they are formed, and with the size of the fragment before becoming waterworn.

As a rule the iron has replaced the substance of the bryozoan itself; all the stages between partial and complete replacement may be noticed, the most complete stages being of course found in the purer ores. Usually, corresponding changes are observed in the cement which binds the oolitic grains together into a solid mass. It is evident in these cases that the origin of the oolitic structure is not due to a concretionary segregation of iron particles, but finds its explanation in the gradual replacement of the lime of the fragmental fossil bryozoans, particle after particle, by the iron ore. When the bryozoans themselves have been replaced by iron ore, but the lime cement filling their original cell cavities has been but slightly altered, the sections of these grains under the microscope often present a very beautiful appearance.

At other times, especially in cases of bryozoan remains having cells of large size, the reverse is true, the lime of the bryozoans being little altered, while that of the cement once filling its cells, has been replaced by the iron ore. In this case

sections of the round iron ore grains are seen under the microscope to be divided into separate areas, between which the remains of the original bryozoans are still represented by calcite, showing their original cell structure. A beautiful case of this kind was collected by Dr. T. W. Harris, of Harvard University, from the Clinton oolitic iron ore, two miles below Rochester, New York, in the Genesee River, and kindly communicated to me.

The structures here described may, however, be observed over a much wider area. Microscopically valuable specimens were examined by me from the Clinton near Northumberland, Pennsylvania, and at Wildwood Station, Georgia. In fact these Clinton water-worn bryozoan remains are found throughout the Alleghany fields wherever Clinton oolitic iron ores occur.

Similar sections were also obtained from the Clinton oolitic iron ores at Todd's Fork, north of Wilmington, Ohio.

As might be expected from the foregoing remarks, both the bryozoan fragments and the cement filling their cells, since both are composed of calcite, are frequently replaced so completely by the iron ore that no traces of their original structure remains. All intermediate stages of alteration are of course present. In no case, however, was any thing noticed leading to the opinion that concretionary segregation of iron had taken place, either around the bryozoan fragments or otherwise. Simple replacement by iron ore was the rule, the attack being made first on the exterior parts of the grains.

The bryozoan fragments evidently belong to many species. It would be rash to attempt to identify the species, since the more fragile bryozoans of the Clinton Group have as yet received little study. The branching forms, as might be expected, are most largely represented. The most common are forms having cells arranged in radiating manner around an imaginary axis, but the bilateral Ptilodictydæ and Stictsporidæ are also represented. I see no reason for believing them to be other than good Clinton species.

It might be interesting to speculate as to what reduced these bryozoan remains to their present rounded forms. Of course this must have been due to currents in the Clinton ocean. But whether their presence is due to the waters of a *shallow* sea or not, and whether they indicate the proximity of *shore* conditions, I am not prepared to say. It will be pertinent, however, to state that the shores of the Clinton sea do not seem to have been far distant from the present metamorphic axis of the Alleghany system, and that the oolitic deposits mentioned from Ohio are found within 32 miles of the Clinton conglomerate at Belfast, Highland County, Ohio.

Art. V.—*Effects of Pressure on Ice;* by R. W. Wood, Jr.

Certain theories regarding the movements of the great glaciers of the ice epoch, depending on the pressure-melting of ice, a number of experiments were performed by the writer, to determine the effect of great pressures on ice masses at various temperatures. The experiments were tried with a hydrostatic press capable of yielding a pressure of one hundred tons on its $6\frac{1}{2}$ inch ram, the first one being made to determine at what pressure ice could be made to flow through a tube of small diameter.

A block of iron was cast measuring $6\times4\times4$ inches, and drilled to the depth of four inches with an $1\frac{5}{8}$ inch hole, to which was fitted a solid steel piston, turned with such accuracy that, when oiled, it worked air-tight except under considerable pressure, when a few bubbles oozed through. Into the side of the block a $\frac{1}{12}$th inch hole was drilled, which communicated with the bottom of the cylindrical cavity precisely like the vent of a cannon. The cavity was nearly filled with ice at the melting point, and the steel piston inserted. The apparatus was then put under pressure: for a minute or two water flowed from the hole, with occasional air bubbles which effervesced with a white foam on emerging. The index of the guage showed that the ram was exerting a pressure of about six tons (three tons to the inch, the piston being two square inches in cross section) when the ice began to rise through the small hole. It rose slowly and steadily at first, as a cylinder of clear ice, which broke off when six or eight inches in height, then faster as the pressure increased, until the gauge indicated a pressure of nine tons, when it seemed fairly to spurt from the orifice, pieces two or three inches long being projected to a height of a foot or more into the air. It flowed with an irregular motion, which did not correspond with the strokes of the pump, but seemed to indicate that the ice was in a viscous condition, seeming to stick for a second or two and then yield suddenly. On reversing the press, and removing the piston, what was left of the ice was found moulded into a clear transparent block.

The next experiment was to test at what pressure ice at the melting point would become fluid as a mass. An iron block similar to the one used in the previous experiment, except that it was without the small hole, was filled with ice in which were imbedded several small bullets, the positions of which were carefully noted. The piston was fitted and the mass subected to pressure. The index showed a tension of fourteen

tons, above which point it was difficult to force it, since the ice melted rapidly, and the water oozed out around the piston in spite of its perfect fit. On releasing the apparatus and removing the piston, the bullets were found in the same position; they had not dropped to the bottom of the cavity as they would have done had the mass been reduced to a liquid state, thus proving that under a pressure of seven tons to the inch (933 atmospheres) the ice had remained solid or viscous to such an extent that it could easily support the lead.

These same experiments were repeated under conditions of greater cold: the blocks, after being filled with ice, were exposed to a temperature of about −5° Centigrade until thoroughly chilled, and were then carried to the press. This obviated the difficulty of the rapid melting caused by the heat of the iron. The results obtained, though practically the same, were more marked than in the first experiments. The ice cylinders came out with more violence than before, some fragments being projected to a height of ten or fifteen feet into the air. They were of clear, transparent ice and several inches in length. Small jets of water, in finely divided spray occasionally spurted out around the ice cylinders as they rose from the tube; this spray congealed on falling back upon the block, showing that the iron was below the freezing point.

The experiment with the bullets was repeated with the apparatus chilled below 0° C. A pressure of twenty-four tons was reached before the index of the gauge stopped; water spurted out in a spray around the piston, and instantly froze on the surface of the block as it ran down: ice, too, oozed out in thin sheets. On removing the apparatus it was found that the bullets had not dropped, showing that a pressure of twelve tons to the inch was insufficient to reduce the ice to a liquid state. One bullet which lay close to the wall of the cylinder had been ground between the piston and the wall, and a portion of it was spread out in a thin film over the iron. As a final test, a piece of oiled leather was inserted between the piston and the ice, which effectually prevented all leakage. The index hand moved slowly along until it reached a point indicating forty tons, when suddenly the air was filled with *fine jets of spray* which spurted in all directions from the block. The water had actually permeated the iron, forcing its way through the pores of the metal or breaking minute paths for its exit, and emerged in countless jets from the surface.

This of course put a stop to further experiments, the limit of resistance of the iron having been reached. A calculation will show that in the last experiment the pressure was sufficient to liquefy exactly one-fourth of the ice, being that produced by a column of ice twenty miles high.

Even under this enormous pressure the ice was found to have had sufficient viscosity to support the weight of the shot.

The maximum depth of the ice in the glacial epoch never exceeded two miles and such a mass would yield a pressure of about two tons to the inch, or two hundred and sixty-six (266) atmospheres. Sir William Thomson's experiments show that the melting point of ice is lowered .0075° C. for every atmosphere of pressure, that is to say, a mass of ice subjected to pressure has its temperature lowered .0075° C. for every additional fifteen pounds to the inch. Let us now consider exactly what the effect of a pressure of 266 atmospheres will be: the reduction of temperature will of course be ·0075°×266, or — two degrees Centigrade (more exactly 1·955° C.). Starting with water at 0° we shall then have a mass of ice and water at a temperature of — two degrees Centigrade. To determine the amount of ice melted or reduced to a state of pressure-molten water, we make use of the well-known formula,

$$x = \frac{\text{temperature (in } -\text{degrees)}}{79{\cdot}25}$$

x being a fractional quantity representing the proportion of ice liquefied, and the constant quantity 79·25 being the latent heat of fusion for ice. The result is $\frac{1}{40}$, this being the exact amount of ice that will be liquefied by a pressure of 266 atmospheres. The condition of a lower layer of a mass of ice two miles thick will be as follows. The temperature will be $-2°$ Centigrade, and a certain portion, namely $\frac{1}{40}$, will be in the state of pressure-molten water, which, being diffused through the mass of the ice, will not sensibly diminish its rigidity.

It will be seen that the pressure of such a mass of ice was considerably less than that required to cause ice at the melting point to flow easily and rapidly through a small orifice. It may be argued that the time element has not been considered. Time has nothing to do with the result, except as heat is fed to the bottom layer from the earth. Insulate the mass from all sources of heat, and the equilibrium will remain unchanged until the end of time. The law of conservation of energy decrees that this must be so.

It is true that glacial ice was not thus insulated: that it received heat from the earth we all admit, but let us consider exactly what the effect of this heat supply was. We have at the beginning a temperature of $-2°$ C., and $\frac{1}{40}$ of the ice in a liquid state. Heat is fed from the earth which tends to raise the temperature, but the constant pressure keeps this uniform, and the heat is expended in melting more ice. After a lapse of time we shall have a considerable portion of the ice in a liquid state, but by considering carefully the conditions, we shall see that it is thermo-molten and not pressure-molten.

The temperature remaining constant, as it is bound to do under a constant pressure, we shall have a mass of water at $-2°$ C. underlying a mass of ice of enormous weight. This water has not the properties necessary to prevent its escaping from beneath the ice, for if the pressure be relieved at a crack or break, only $\frac{1}{40}$ of the mass will congeal, which will scarcely be sufficient to seal the means of escape. In other words, as fast as water formed beneath the glacier, it would be squeezed out by the pressure of the ice. The results of these experiments appear to render questionable any theory accounting for peculiar motions of glacial ice by supposing the existence of a layer of pressure-molten water beneath the mass.

ART. VI.—*A Review of the Quaternary Era, with special reference to the Deposits of Flooded Rivers;* by WARREN UPHAM.

TWO stages of great progress in knowledge of Quaternary geology were marked by the publication of the glacial theory by Louis Agassiz fifty years ago, and of "The Great Ice Age" by James Geikie sixteen years ago. And the degree of attention which deposits of this age are now receiving is even greater than ever before. Besides the vast mass of glacial literature which has appeared in the form of scientific papers in magazines and in reports of societies and of government surveys, two popular treatises have been recently published, summarizing what has been done in this field of geologic investigation in this country and in France and the western Alps.* The purpose of the present paper, based on my own observations and on study of the work of others, is to trace concisely the sequence of events during the Ice age and the post-glacial epoch, to discuss the probable causes of the great climatic changes of this era, and to notice especially its remarkable fluvial deposits.

The Quaternary era, according to definitions of recent text-books of geology by Dana, Archibald Geikie, and Etheridge, began with the change from the mild Pliocene climate to that of the Glacial period, with its accumulation of vast sheets of land ice in high latitudes, and has continued to the present time. We are living in the Quaternary era, as thus defined, and it must extend far into the future to be at all proportionate in length with the previous co-ordinate divisions of geo-

* G. F. Wright, The Ice Age in North America, 1889. (Appleton & Co.) A. Falsan, La Période Glaciaire, 1889. (Felix Alcan, 108 Boulevard Saint-Germain, Paris.)

logic time. LeConte and Prestwich, however, consider the Quaternary division of time as completed at the dawn of civilization, with traditional and written history; and they assign recent geologic changes to a new era, which is separated from the preceding principally on account of the supremacy of man. The former view seems preferable, because man is known to have been contemporaneous with the Ice age, and it is therefore adopted in this article, the Quaternary history of our rivers being understood to include their formation and erosion of deposits through all their vicissitudes during and since the Glacial period.

By most writers the terms Pleistocene, Post-tertiary, and Post-pliocene, though etymologically applicable to the whole extent of time from the Pliocene till now, are used restrictively as synonymous with the Glacial period, embracing its stages of beginning, of alternating glacial and interglacial epochs, and of final recession of the later ice-sheets, to which closing stage of Glacial or Pleistocene time the name Champlain period has been given by Hitchcock and Dana, from the marine beds then deposited in the basins of Lake Champlain and of the Saint Lawrence and Ottawa rivers. Investigations of the Quaternary geology of the United States by McGee, Chamberlin, Gilbert, Russell, and others, have shown that the Glacial period or Ice age was complex, comprising in this latitude three principal epochs, namely, the first glacial epoch, with minor oscillations of the boundary of the ice-sheet upon the northern United States, culminating in its maximum southward extension to Cincinnati, Saint Louis, and Topeka, but leaving a large tract unglaciated in southwestern Wisconsin and the edges of adjoining states; then, a long interglacial epoch, in which the ice-sheet was melted back far to the north, or indeed quite probably may have wholly disappeared from this continent, while many of our rivers eroded deep channels through the bed-rocks, leaving here and there high terraces and deserted portions of the courses which they had occupied during the earlier glaciation; and, lastly, the second glacial epoch, when again ice was accumulated in great thickness upon the country, reaching south to Nantucket, Martha's Vineyard, Long Island and Staten Island, and into northern New Jersey and northern Pennsylvania, throughout this distance attaining at least as great extension as the earlier ice-sheet, but farther westward across the Mississippi basin falling short of the early glacial boundary by a width that varies from a few miles to about 275 miles. Both the growth and departure of the later ice-sheet, and also of the earlier, appear to have been marked by irregular stages of advance, retreat, and re-advance, many times repeated, as shown by vegetal deposits, as trunks and

branches of trees, layers of peat, or patches of the old surface soil, enclosed between deposits of the till or unmodified glacial drift, and by numerous roughly parallel and interlocking belts of hilly and knolly drift, amassed as terminal moraines at the margin of the ice during its interrupted and oscillating final retreat.

Extensive and thick beds of gravel, sand, and clay or fine silt, called stratified or modified drift, were deposited in valleys which received the drainage from the glacial melting, especially during its comparatively rapid progress in the Champlain period. The dissolution of the ice, with accompanying rains, produced extraordinary floods along all the rivers flowing away from the waning ice-sheet; and these were heavily laden with detritus set free from the ice in which it had been held, and brought down by the rills and small and large streams formed on the melting ice surface. Other portions of the englacial drift were let down as till in a loose unstratified mass upon the subglacial till or ground moraine, making the Champlain epoch, as Professor Dana has shown, preëminently one of abundant deposition, both of stratified and unstratified drift.

This epoch was immediately succeeded by one of rapid erosion of the valley deposits, as soon as the continued glacial recession beyond the drainage areas of the rivers cut off the supply of water and of drift that had been derived from the melting ice. The resulting excavation of the glacial flood-plains has left remnants of those deposits in conspicuous terraces along all our river valleys which lead southward within the glaciated region or on its southern border; and postglacial time, extending to the present day, is therefore named by Dana the Recent or Terrace period. It is to be remarked, however, that much of the terracing of the valley drift was doubtless done speedily after the retreat of the ice from any basin, while yet adjacent drainage areas on the north were receiving from it thick flood-plain deposits. The Glacial, Champlain, and Terrace periods thus overlap, the second being wholly, and the third partially included within the Glacial or Pleistocene period, if continental areas are considered; but for any limited district, as a single river basin, the sculpturing of the terraces took place chiefly after the departure of the ice beyond its water-shed.

Deposition and erosion by rivers are determined by their rate of descent, their volume, and the amount of detritus which they hold in suspension, received along the higher portions of their course. All these conditions have been subject to important changes during the Quaternary era, not only for the regions that became ice-covered in the Glacial period, but also for many other parts of the earth's surface. The efficiency of

the rivers in erosion, transportation, and deposition has been often increased by these changes, with the result that abundant fluvial deposits have been spread upon the land, along the valleys and in great alluvial plains. At the same time an immense tribute of river silt has been borne forward to the sea and forms a part of the submerged margins of the continental plateaus. If the proportion of the deposits made by the rivers before reaching the sea appears to be greater than in previous eras, the contrast is probably attributable to the more general preservation of marine than of fresh-water formations, the latter being liable to repeated erosion until they finally are carried beneath the level of the ocean.

Foremost among the Quaternary changes affecting river action have been oscillations of the land, both of continental areas and of mountain ranges. Fiords and submerged valleys indicate that the glaciated areas of North America and Europe have been elevated 2,500 to 3,000 feet above their present level. The district intersected by the Grand Cañon of the Colorado has been uplifted, according to Powell and Dutton, not less than 6,000 feet, causing the river to erode to this depth, during Pliocene and Quaternary time; and the latest comparatively rapid elevation, amounting to about 3,000 feet, the depth of the inner or lower part of the cañon, is referred to the early Quaternary. In this epoch, also, great uplifts and subsidences by faulting have taken place, as shown by Powell, LeConte, and Diller, in the Great Basin region, with its monoclinal mountain ranges consisting of blocks of faulted but not usually flexed or folded strata; while the lofty Sierra Nevada has the same structure, and attained its present prominence at the beginning of the Quaternary era. In South America the observations of Alexander Agassiz show that the Peruvian Andes have experienced Quaternary uplifts of 2,900 feet, or perhaps much more; and Medlicott, Blanford, and other explorers find that much of the mountain-building of the Himalayan range, and the formation of the table-land of Thibet, belong to the same latest era of geologic time, and that large tracts of central and northwestern Asia have contemporaneously risen out of the sea. These upward movements, generally followed in glaciated regions by depression while the land was ice-covered, but mainly permanent or only partly counteracted by subsequent sinking in the mountain ranges, have given to the rivers temporarily or permanently steep gradients and consequent increase of power to erode and transport material, which has been often deposited in very extensive gently sloping plains along their lower courses, on account of the decrease there in the rate of their descent and the slackening of their velocity.

Before considering these river deposits, however, we shall need to inquire somewhat more in detail what movements of elevation and subsidence have affected our own continent, and what have been the influences of Quaternary climatic conditions, and of the ice-sheets, upon the volume of our rivers and upon the supply of detritus which they have transported.

The evidences of great uplift of North America preceding the Pleistocene period have been impressively stated by Prof. J. W. Spencer.* The submarine border of the continent is cut by valleys or channels, which are doubtless river-courses that were eroded while the land stood higher than now; and its subsidence evidently took place in a late geologic period, else these channels would have become filled with sediments. According to the United States Coast Survey charts, as noted by Spencer, the bottom of such a submerged valley just outside the delta of the Mississippi is found by soundings at the depth of 3,000 feet. The continuation of the Hudson River valley has been traced by detailed hydrographic surveys to the edge of the steep continental slope, at a distance of about 105 miles from Sandy Hook. Its outermost twenty-five miles are a submarine fiord three miles wide and from 900 to 2,250 feet in vertical depth, measured from the crests of its banks, which with the adjacent flat area decline from 300 to 600 feet below the present sea level.† Again, the Coast Survey and British Admiralty charts, as Spencer states, record submerged fiord outlets from the Gulf of Maine, the Gulf of Saint Lawrence and Hudson Bay, respectively at depths of 2,664 feet, 3,666 feet and 2,040 feet. In California, too, Prof. George Davidson, also cited by Spencer, reports three submarine valleys about twenty-five, twelve, and six miles south of Cape Mendocino, sinking respectively to 2,400, 3,120 and 2,700 feet below the sea level where they cross the 100 fathom line of the marginal plateau.

Preglacial elevation of this continent is further attested, but without supplying measurements, like the foregoing, of its great extent, by the eroded areas of Pamlico and Albemarle sounds, and of Chesapeake and Delaware Bays; by the fiords of Maine, of all the coast northward to the Arctic regions, and of the Pacific Coast south to Vancouver Island and the Columbia River; by the Golden Gate, which has a maximum depth of 414 feet; and by the islands south of Santa Barbara and Los Angeles, which were united with the mainland during the later Pliocene and early Quaternary periods, as Pro-

* Bulletin, Geol. Soc. of America, vol. i, 1889, pp. 65–70; also, Geol. Magazine, III, vol. vii, pp. 208–213, May, 1890.

† See Prof. J. D. Dana's recent discussion of the submarine Hudson river channel, with map reduced from a chart of the U. S. Coast Survey, this Journal, III, vol. xl, pp. 425–437, Dec. 1890.

fessor LeConte has shown, whereas now they are separated from the mainland and from each other by channels twenty to thirty miles wide and 600 to 1,000 feet deep.

The general absence of marine Pliocene formations in North America and northern Europe indicates that the areas on which ice-sheets were accumulated in the Glacial period had long stood higher than now; and this elevation probably was shared, in its culmination, by our entire area north of the Gulf of Mexico, including even our southeast coast from the Carolinas to Florida, where scanty Pliocene beds are found. The altitude attained by this continent was about 3,000 to 3,500 feet, if not more, above its present level, as is known by the valleys that were then eroded on the margin of the continental plateau but are now submerged. The greatest height seems to have been reached in the early part of the Quaternary era, causing snowfall to prevail, instead of rain, throughout nearly the whole year in what are now temperate latitudes, and thus inaugurating the Ice age. South of the glaciated area, the Allegheny Mountains and all the southern part of the United States received increased precipitation of snow in winter, but it was melted by the warmth and rains of summer.

If this view is true, that the great elevation of the land was the principal cause of its glaciation, the height must have been maintained during a considerable time, sufficient for the accumulation of thousands of feet of ice; and after an interval of subsidence, at least for the southern part of the region, marked by the interglacial epoch, we must suppose that another uplift brought on the later ice-sheet. But the whole extent of the time during which the land was held at great heights by the successive uplifts could only have been a small part of the Quaternary era; for such elevation would evidently afford as favorable opportunity for erosion by the rivers in their steep descent on the margin of the continental plateau as has been granted to the Colorado River in the erosion of its Grand Cañon. We may therefore infer that the combined length of the Glacial epochs bears somewhat the same ratio to the entire Quaternary era as the extent of the short submarine fiord of the Hudson bears to that of the long and more profound inner cañon of the Colorado.

The uplift of North America in late Tertiary time brought to the partially or almost wholly base-levelled basins of rivers on the Atlantic slope and in the central United States a new cycle of erosion, as Davis and Wood have shown in northern New Jersey,* and President Chamberlin for the Upper Mississippi and its tributaries.† Tertiary erosion, probably most

* Proceedings, Boston Society of Natural History, vol. xxiv, 1889, pp. 393, 412.

† U. S. Geol. Survey, Sixth Annual Report, pp. 222–4. Geology of Wisconsin, vol. i, p. 255.

active during the Pliocene period, has produced the main features of the present valleys of the Mississippi and Ohio Rivers; and in the latter the smoothly flowing outlines and moderate slopes of the surface shaped by this erosion present a remarkable contrast with the steeper sides of the inner or lower part eroded during Quaternary time.

The highest gravel terraces of the Ohio are found at the line thus dividing the Tertiary and Quaternary erosion, and these terraces contain material supplied from the drift of the first Glacial epoch.* The ice-sheet of this epoch stretched south to the northern tributaries of the Ohio, and even crossed this river at Cincinnati, probably damming back its waters for some short time, and perhaps repeatedly, to form a lake along the Ohio to Pittsburgh and far beyond up the confluent Allegheny and Monongahela valleys. A glacial dam could exist, however, only at the stage of maximum advance of the ice, and its short duration permitted little record in terrace or delta deposits. The high terraces before noticed are of fluvial formation, apparently belonging chiefly to the time of the recession of the earlier ice-sheet, when the floods supplied by its melting were discharged along this valley, bringing part of its englacial drift and laying it down as a gently sloping fluvial plain of gravel, sand and silt.

On the Ohio, Allegheny, Susquehanna and Delaware Rivers, below their highest terraces and scanty remnants of the flood-plains of the first Glacial epoch, Chamberlin and McGee find that interglacial erosion deepened the valleys 200 to 300 feet through the hard bed-rocks before the epoch of the later glaciation.† The drift of this second Glacial epoch is distinguished from that of the first, which has a greater extent in the Mississippi basin, by terminal moraines formed on the extreme boundary of the later ice-incursion and at successive stages of halt or re-advance of the ice-sheet during its departure. A long interglacial epoch, as measured by years, must have divided the epochs of glaciation, and its cause was probably a considerable subsidence of the continent, or at least of the eastern United States and the Mississippi basin, but apparently not to the sea level. That there was greater altitude, and probably more descent from north to south during the interglacial epoch than during the Tertiary erosion, is indicated by the narrowness and steep sides of the Quaternary portion of these valleys.

From the observations thus made in valleys tributary to the Atlantic ocean and the Gulf of Mexico, the earliest Quaternary record for the northern part of that area appears to be the

* Chamberlin and Wright, Bulletin No. 58, U. S. Geol. Survey.

† Bulletin Geol. Soc. of America, vol. i, pp. 472–4.

envelopment of the land with an ice-sheet, which extended on the Ohio and the Mississippi to the extreme southern limit of the till and glacial striæ. But in the Great Basin and Sierra Nevada region early Quaternary events, according to LeConte and Diller, were the formation of immense faults, by which the mountain ranges were upheaved, the turning aside of rivers from their former courses, and the outpouring of lavas, which are often found capping the old auriferous river gravels.* In the long interglacial epoch of the northeastern area, the Sierra Nevada and Great Basin ranges were undergoing erosion at a far more rapid rate than the valleys of the eastern rivers; and to this time we must assign the accumulation of the greater part of the very thick alluvial deposits of the arid region, which are called "adobe" and compared with the loess of China by Russell.

The ensuing second Glacial epoch, with a southward advance of the ice on the Atlantic coast beyond that of the earlier glaciation, was probably induced by a geologically sudden, high uplift of the northeastern part of the continent; and in the Upper Mississippi region, according to Chamberlin and Salisbury, the differential elevation, increasing from south to north, was 800 or 1000 feet. As an uplift of the continental plateau, but without much disturbance of its mountain ranges and of the general contour of the great interior area, this movement appears to have embraced the entire width of the country, raising the Rocky, Sierra Nevada, and Cascade mountains to such altitude that large tracts became covered by glaciers.

Influenced by the changed climatic conditions, with increase in the precipitation of snow and rain, and decrease in the rate of evaporation, many enclosed basins of the arid region, which had previously been dry or only occupied by shallow lakes, became filled almost or quite to overflowing. Two of these Quaternary lakes, especially important because of their size, namely, Bonneville in Utah and Lahontan in Nevada, have been described respectively by Gilbert and Russell in monographs of the U. S. Geological Survey. Each of these lakes is found to have a history of two epochs of humidity, with great rise of their waters, divided by a very dry epoch, in which they were lowered by evaporation until little or no water remained. These lacustrine and interlacustrine stages in the Great Basin do not appear, however, to represent the first and second Glacial epochs of the northeastern states, with their interglacial epoch; but, as indicated by their place in the sequence of Quaternary events, they seem referable to the

* This Journal, III, vol. xxxii, pp. 167–181, Sept., 1886, and vol. xxxviii, pp. 257–263, Oct., 1889. U. S. Geol. Survey, Eighth Annual Report, pp. 428–432.

second Glacial epoch, showing that it was more prolonged and complex there than eastward. Indeed, so definite subdivision of the lacustrine history of the arid region, and its relationship with the glaciers, living and extinct, of that region and of the country thence north to Alaska, lead us to ask whether there has not been a third as well as a second Glacial epoch, the last affecting chiefly the far west and far north.

Recession and final melting of the ice-sheet of the second Glacial epoch from the Upper Mississippi basin, the Laurentian lakes, and New England, took place only 7,000 to 10,000 years ago, according to estimates by Prof. N. H. Winchell, from the rate of the postglacial erosion of the falls of Saint Anthony;* by Dr. Andrews, from the erosion of the bluffs bordering Lake Michigan, and the resulting accumulation of sand beaches and dunes about the south end of the lake;† by Professor Wright, from the formation of valleys by streams tributary to Lake Erie;‡ by Mr. Gilbert, from the Niagara gorge and falls;§ and by Professor Emerson, from alluvial deposits of the Connecticut River.‖ The moraines stretching from Nantucket and Cape Cod west to the Dakotas, Manitoba and Assiniboia, are thus referred to a surprisingly late epoch, almost verging upon the historic period of dawning civilization in Egypt, China and India. The first great rise of Lakes Bonneville and Lahontan was apparently contemporaneous with the ice-sheet of the second Glacial epoch, which formed these moraines, and with the maximum extension of glaciers in the western Cordilleran region. After this there followed a very dry climate in the far west, as shown by the Bonneville and Lahontan sediments and shore-lines, corresponding doubtless to the time of departure of the last ice-sheet from the northern United States and the greater part of Canada.

The second rise of Lakes Bonneville and Lahontan belongs to a later time when the far west again had a plentiful precipitation, which was largely snowfall on the Sierra Nevada and northward through British Columbia and Alaska, causing a great development of glaciers and ice-sheets upon the Pacific side of our continent. The date of this glaciation, which may be called our third Glacial epoch, was, according to Russell, "hundreds, but not thousands, of years ago."¶ It is probable

* Geology of Minnesota, Fifth Annual Report, for 1876; and Final Report, vol. ii, 1888, pp. 313–341. Quart. Jour. Geol. Soc. London, vol. xxxiv, 1878, pp. 886–901.

† Transactions of the Chicago Academy of Sciences, vol. ii.

‡ The Ice Age in North America, p. 466.

§ Proceedings, Am. Assoc. Adv. Sci., vol. xxxv, for 1886, p. 222. "The History of the Niagara River," Sixth An. Rep. of Commissioners of the State Reservation at Niagara, for 1889, pp. 61–84.

‖ This Journal, III, vol. xxxiv, pp. 404–5, Nov., 1887.

¶ U. S. Geol. Survey, Monograph xi, Geological History of Lake Lahontan, p. 273. Bulletin, G. S. A., vol. i, p. 142.

that this return of glacial conditions affected also the Mackenzie basin and the country bordering Hudson Bay, as seems to be indicated by the observations of Dr. Robert Bell.* In New England and the Saint Lawrence region, and in Greenland, Iceland, northwestern Europe, and even Spitzbergen, this refrigeration, following an interval of somewhat warmer climate than that which prevails at the present time, has caused the isolation of colonies of southern mollusks whose geographic range must have been formerly continuous from southern latitudes; and corresponding changes in the forests and other flora of the land are discovered in European peat-bogs.† Very probably these recent climatic changes, both marine and terrestrial, in the North Atlantic region, have been due in large measure to variations in the volume of the Gulf Stream;‡ but in the Cordilleran area, from the Sierra Nevada and the contiguous great Quaternary lakes north to Alaska, the increased precipitation of rain and snow and the extension of glaciers, constituting for that area a third Glacial epoch, were probably caused by elevation of that side of the continent. Evidences of very late uplifting of our Pacific coast, followed now by subsidence, in harmony with this explanation of the late glaciation there, have been observed by Dr. G. M. Dawson, but the extent of this uplift may have greatly exceeded his estimate.§

What has been the length of the Quaternary era, we cannot yet determine with very close approximation; but from the extent of river erosion during the principal interglacial epoch, and from many other correlative observations, McGee concludes, as it seems to me reliably, that the interval between the first and second Glacial epochs was several times longer than the interval between the close of the second Glacial epoch, when the latest ice-sheet of the northeastern United States was melted away, and the present day.‖ In proportion with the estimates of 7,000 to 10,000 years for the time since that glacial recession, it appears probable that the whole Quaternary era, including the stages of glaciation and the warm intervals of retreat or complete departure of the ice-sheets, that is, all the period from the end of the Pliocene till now, may be 100,000 or 200,000 years. Though the earliest glaciation is thus apparently referable to some part of the last stage of maximum eccentricity of the earth's orbit, the astronomic theory so ably advocated by Croll seems untenable, not only from the mete-

* Bulletin, G. S. A., vol. i, p. 308.

† This Journal, III, vol. vii, pp. 134–8, Feb., 1874. James Geikie, Prehistoric Europe, chapters xx and xxi.

‡ American Geologist, vol. vi, pp. 336–7, Dec., 1890.

§ Canadian Naturalist, new series, vol. viii, pp. 241–8, April, 1877.

‖ This Journal, III, vol. xxxv, pp. 465–6, June, 1888. U. S. Geol. Survey, Seventh Annual Report, pp. 637–9.

orologic objections of Woeikof, but also from the recurrence of intense glacial conditions during the second and third epochs of glaciation, long after the earth's eccentricity had diminished to its present long minimum stage.

The western margin of the drift spread upon the northern part of the great plains, in Alberta, belonging to the first Glacial epoch, overlies moraines of the Rocky Mountain glaciers; and it seems most probable that this earliest epoch of glaciation brought the maximum extension and thickness of ice in British Columbia, where Dr. Dawson finds that it overtopped mountains from 5,000 to 7,200 feet above the sea.* Continuous land-ice, broken only by the projecting highest Cordilleran ranges, then extended, if my interpretation of the origin of the drift deposits of our interior area is true, from New England, Newfoundland and Labrador, to Vancouver Island, the upper part of the Yukon basin, and the Arctic Sea east of the Mackenzie River. But the division of this ice-covered area by the main Rocky Mountain range, rising, at least in portions of its course, above the *mer de glace*, and containing glaciers in its alpine valleys, may well be recognized by the names Laurentide and Cordilleran, proposed by Dr. Dawson respectively for the ice-sheet of the northeastern part of our continent and for that covering British Columbia. The thickness of the Laurentide ice-sheet of the first Glacial epoch, along its belt of maximum development, was probably 3,000 to 6,000 feet over central Newfoundland and Labrador, increasing to 10,000 or 12,000 feet on the Laurentide highlands and in the basin of James Bay and over the south part of Hudson Bay, but thence decreasing to 8,000 or 7,000 feet in the region of Reindeer and Winnipeg Lakes, and farther west to only 2,000 or 1,500 feet at the Cypress and Sweet Grass hills; while the central part of the Cordilleran ice-sheet, according to Dawson, was from 2,000 to 6,000 feet thick, lying on a very uneven mountainous country. I have estimated the area of North America covered by these ice-sheets as about 4,000,000 square miles, and the probable average thickness of the ice about 3,600 feet, or two-thirds of a mile.†

The ice-sheet of the second Glacial epoch had an ascending slope of twenty to thirty feet per mile from its southern border to Mt. Katahdin, the White Mountains, and the Adirondacks, where its altitude was about one mile above the present sea level, with a thickness of 4,000 to 5,000 feet above the land surface. Its greatest thickness, estimated by Dana to have been 11,000 feet, was on the Laurentide highlands, be-

* Geological Magazine, III, vol. vi, pp. 350–2, Aug., 1889. Am. Geologist, vol. vi, pp. 153–162, Sept., 1890.

† The Ice Age in North America, p. 579. Am. Geologist, vol. iv, pp. 165–174 and 205–216, Sept. and Oct., 1889.

tween Montreal and Hudson bay, as is indicated by the general divergence of striæ and dispersal of drift from that area. This ice-sheet was probably 6,000 feet thick over Reindeer and Winnipeg lakes, but westward it declined to its outermost terminal moraine east of the Hand, Cypress, and Sweet Grass hills, which had been islands surrounded by ice during the the earlier glaciation. In the far western Cordilleran region, however, the ice of the second and third Glacial epochs probably nearly equalled, or in some portions exceeded, that of the first. While the second glaciation fell short of the earlier in the Mississippi basin and on the great plains, it passed beyond that on the Atlantic coast; and likewise, with the third glaciation, it covered and obliterated most of the earlier glacial records in the Rocky Mountains and westward. Throughout the drift-bearing area traces of the last glacial movements, and of the conditions attending the retreat of the latest ice-sheet, are much better preserved than those of preceding stages in the Glacial period; and similarly the relative levels of land and sea at the time of disappearance of the ice are displayed very clearly.

Jamieson twenty-five years ago suggested that the ice of the Glacial period might cause a subsidence of the earth's crust beneath it, because of the pressure of its immense weight, the crust being supposed by him to rest, in accordance with the laws of equilibrium of flotation, upon the heavier molten interior of the earth.* Subsequent researches of glacialists strongly support this opinion, for most countries that have been ice-covered, though previously much elevated, are found to have stood lower than now in relation to the sea level when the ice disappeared, since which time they have risen to their present height. In the interior of this continent the depression of the land beneath the ice-sheet of the first Glacial epoch is shown by the loess of the Missouri and Mississippi basins, which seems to be a deposit of broad slackened river floods and of shallow lakes adjoining the ice-front. On the Atlantic coast the Champlain subsidence attending the close of the second Glacial epoch is known, from fossiliferous marine beds overlying the till, to have been slight in northeastern Massachusetts, 150 to 230 feet in New Hampshire and Maine, nothing or of small amount in Nova Scotia, but considerable, with increase from east to west, along the lower Saint Lawrence valley, being 375 feet opposite the Saguenay, and 520 feet at Montreal, but thence diminishing southward along lake Champlain and westward in the upper Saint Lawrence and Ottawa valleys. The country southwest of Hudson bay sank 300 to 500 feet, Labrador 1,000 to 1,500 feet, and western Greenland

* Quart. Jour. Geol. Soc. London, vol. xxi, 1865, p. 178.

and Grinnell Land 1,000 to 2,000 feet. Again, in British Columbia and the Queen Charlotte Islands, Dr. Dawson and others find proofs of submergence, ranging up to 200 or 300 feet, while the glacial conditions still endured.

Northwestern Europe, also, had a much greater altitude during the later part of the Tertiary era, in which Scandinavia and the British Isles suffered vast denudation, with erosion of fiords and channels that are now submerged 500 to 800 feet beneath the sea. The maximum preglacial elevation probably exceeded the depth of the Skager Rack between Denmark and Norway, which is 2,580 feet, with a deep submerged valley running from it west and north to the abyssal Arctic ocean.* Under the weight of its ice-sheet, the glaciated area of Europe, like that of North American, sank mostly to a somewhat lower level than it now has, the maximum depression in Scotland, Sweden and Norway, and Spitzbergen, being 500 to 580 feet.† From this depression Scandinavia has gradually risen, with pauses, during which beaches were formed ; and the uplift of that peninsula, as of the country about Hudson bay, continues to the present day.‡

The climatic conditions of the Ice age were very favorable for the production of river floods. During the times of great continental elevation and the accumulation of ice-sheets, the highlands and mountains south of the glaciated areas received in the winters far more snowfall than now, and in the summers this was melted fast, giving the streams far greater volume during their stages of flood than at the present time. The approximate parallelism of the southern boundary of the ice-sheets with the present isothermal lines and with belts of equal precipitation of rain and snow, indicates that the distribution of heat and the courses of storms were somewhat the same as now. It seems to be proved, however, by the abundant occurrence of Pleistocene fossils on the isthmus of Panama, "all living up to the present time," collected by Dr. G. A. Maack up to the height of 763 feet,§ that the lower portions of this isthmus were submerged once, or perhaps repeatedly, during the Glacial period, permitting the warm equatorial current of the Atlantic to continue right onward into the Pacific ocean, instead of flowing northeastward out of the Gulf of Mexico. A large amount of warmth would thus be withdrawn from the northern Atlantic area. It is also probable that the part of the bed of the North Atlantic stretching

* Nature, vol. xxiii, p. 393, with map of submarine contour.

† Am. Geologist, vol. ii, pp. 375–6, Dec. 1888. Geol. Mag., III, vol. vi, 1889, pp. 157–8. Nature, vol. xv, p. 123, and vol. xxxii, p. 555.

‡ Nature, as last cited, and vol. xxxix, pp. 488–492.

§ Reports of Explorations for a Ship Canal, Isthmus of Darien, Navy Department, Washington, 1874, pp. 155–175.

from France and Great Britain to the Færöe islands and thence to Iceland and Greenland was uplifted to form a continuous land surface, remaining thus so long as to be a bridge for the migration of the European flora after the departure of the ice.* On the whole, however, there was probably not less evaporation from the sea, and not less precipitation from the clouds, than now. Upon the most elevated areas the moisture received from the clouds was temporarily stored as ice; while in contiguous mountain districts, as the southern Appalachians, the excessive winter snows were each year melted and poured down in floods across the plains between the mountains and the ocean. And on the glaciated areas, when the ice-sheets were at any time forced to retreat, and especially during their final melting, great floods of water from the dissolving ice and from accompanying rains swept down from the ice-surface, filling the valleys of the adjoining land and spreading over its plains in their seaward course.

Unusually abundant detritus was supplied to the Quaternary river floods, both on unglaciated areas and on tracts that had been ice-covered. For example, our southern Appalachian district had been subjected to very long continued subaërial denudation under a more equable climate and at less altitude during the Tertiary era, and a large amount of detritus rested on the mountain slopes and in the high valleys, ready to be carried away to the lower plains by the swollen rivers at times of Quaternary uplifts of the continent and northern glaciation. Within the ice-sheets, too, much drift was gathered up from the general land surface over which the ice slowly moved outward from its central area; and especially the sides of hills and mountains, rasped by the overriding ice, yielded plentiful bowlders and coarse and fine rock-débris, which was borne forward as englacial drift, to become part of the ground moraine farther on, or to be dumped in the terminal moraines, or, not reaching these, to be exposed on the surface of the ice during its departure. The osars and kames, and the abundant stratified drift of valleys and plains in glaciated countries, show that the amount of englacial drift was large, and that much of it was carried off to form these deposits by the flooded rivers that descended from the melting ice.

Attempting a correlation of the Quaternary fluvial deposits of this country, we may notice first those which were formed upon areas beyond the limits of the glacial drift. In the southern Atlantic states the Appomattox and Columbia formations, described by Mr. McGee as marine beds, characterized by coarse cobble and gravel deposits, with ice-borne bowlders,

* Andrew Murray, Geographical Distribution of Mammals, 1866, pp. 37–42. James Geikie, Prehistoric Europe, 1881, pp. 518–522, and p. 568, with plate E.

along the rivers, and prevailingly finer gravels, sand, clay and silt between the rivers, seem to me referable to fluvial action, dependent on the conditions already noted, without submergence by the sea, during times of great Quaternary elevation of the continent, while its northern part was becoming covered with the ice-sheets of the first and second Glacial epochs. The lack of fossils accords better with such deposition by flooded rivers; and, in harmony with this view, the stratigraphic relations indicate for the Appomattox an early Quaternary age, and for the Columbia a much later age, yet antedating that of the terminal moraines and stratified valley drift of the adjacent glaciated area of Pennsylvania, New Jersey, and Long Island, which belong to the culmination, and in larger part to the stages of recession, of the later ice-sheet.*

In the lower Mississippi basin, the great uplift introducing the earlier glaciation seems to have been marked by so excessive precipitation and heavy river-floods that thick deposits of sand and gravel, constituting the principal mass of the "Orange Sand," were filled into the channel which had been cut by the river in the Tertiary beds of its lower course while it was above the sea level, but had only a moderate elevation, during the greater part of the Pliocene period. About the time of the maximum extension of the ice-sheet of the first Glacial epoch, this basin was depressed to approximately the height which it now has, but with less descent in its slope seaward, as shown by the loess. On account of the diminished transporting power of its floods, deposition along the lower valley ceased for a time, and the "Orange Sand" was partially eroded, until at length the floods and silt supplied by the melting of the ice-sheet filled the newly formed channel, and overspread the gravel and sand areas, depositing the Port Hudson beds and loess. During the long interglacial epoch these beds, with the "Orange Sand," were immensely eroded, and more especially at the time of northward elevation initiating the second Glacial epoch. Again, from the melting of the later ice-sheet, vast floods, bringing some gravel and sand, but more fine silt or loess, poured down this valley, spreading their deposits along the bottom of the interglacial channel in a flood-plain 200 to 300 feet below the uplands and sixty miles wide from Cairo southward; and, at a diminished rate, the deposition of the river silt over this bottom-land is still going on at every flood stage.†

* This Journal, III, vol. xxxv, Feb., and April to June, 1888; vol. xl, pp. 15–41, July, 1890; and vol. xl, pp. 237–8, Sept., 1890.

† E. W. Hilgard, this Journal, II, vol. xlii, May, 1866; vol. xlvii, Jan., 1869; vol. xlviii, Nov., 1869; III, vol. ii, Dec., 1871. T. C. Chamberlin, Bulletin Geol. Soc. of America, vol. i, 1890, pp. 469–480.

Quaternary silt deposits, closely related to the loess, form broad expanses in the Great Basin and in the San Joaquin valley of California, attaining depths of at least 1,500 to 2,000 feet and more, as is known by artesian borings which at these depths fail to reach the bed-rock. These deposits consist mainly of fine-grained calcareous earth or clay, porous, gray to yellow in color, which is used by the Indians and Mexicans for the manufacture of sun-dried bricks, known by the Spanish name "adobe." This name is also used for the earth from which the bricks are made, and Russell has therefore adopted it for this extensive geologic formation of the arid region. Its broad flat tracts are bordered by steep mountain ranges, and others rise from it like islands. The origin of the adobe, as Russell has shown, is from the waste of the mountain slopes, chiefly through the action of ephemeral rills and streams, born of passing showers.* Though it is still increasing in thickness, evidently far the greater part of this formation was deposited before the humid epochs recorded by lakes Bonneville and Lahontan, but after the early Quaternary orographic movements which produced the grand topographic features of the region. It belongs therefore mainly to the first Glacial epoch and the ensuing long interglacial epoch.

Russell has solved the difficult problem of the loess of China by comparing it with the adobe; and the great Quaternary deposits of the Mississippi valley, and of the coastal plain of the Southern States, find analogues in the basins of the Amazon and La Plata, of the Rhine and the Po, of the Nile, of the Indus and Ganges, of the Yang-tse Kiang and Hwang Ho, and of the Lena, Yenisei, and Obi. In particular, we may compare the great Indo-Gangetic plain, which stretches across India south of the Himalayas, with the Appomattox and Columbia formations. This immense alluvial plain, the richest and most populous portion of India, covers about 300,000 square miles, rising from the sea level to an elevation exceeding 900 feet on the water-shed between the Indus and the Ganges. Its prevailing formation is fine silt or clay, more or less sandy, with gravel near the borders of the plain. Its central portions have a thickness of at least 400 to 700 feet, as determined by borings which do not at these depths reach the bottom of the alluvium; and this entire deposit, according to Medlicott and Blanford, is of Quaternary age and of fresh-water origin, having been laid down by the flood stages of the rivers that descend from the very rainy southern slopes of the Himalayan range.†

The stratified or modified drift, gathered from the ice-sheet by superglacial and subglacial rivers, and spread beyond its

* Geol. Magazine, III, vol. vi, pp. 289–295 and 342–350, July and August, 1889.

† Manual of the Geology of India, 1879, Part i, pp. 391–421. Quart. Jour. Geol. Soc. London, vol. xix, 1863, pp. 321–354.

area, most abundantly during stages of glacial recession, has been observed and often well described and mapped in all glaciated countries which have received study, but perhaps nowhere else so fully as in the valley of the Connecticut river.* This beautifully terraced valley, the terraces and plains of the Merrimack river, and the osars and associated plains of Maine which Stone has so well described, illustrate the formation of the modified drift deposits where free drainage could take place from the border of the ice-sheet. Beds of gravel, sand and clay filled the Connecticut and Merrimack valleys to the level of their highest terraces, which are remnants of the glacial flood-plain, and the lower terraces record stages of the subsequent erosion. Every large river valley running southward within our glaciated area has had an interesting history, which may be discovered by study of its stratified drift. Owing to the northern depression of the land under the ice-weight, the descent of these valleys when first uncovered from the ice was generally less than now. In the Hudson valley the changed levels appear to have included not only subsidence at the north, which admitted the sea to the basin of lake Champlain, but also elevation of the present coast above the sea on the latitude of New York city and southward, so that while the ice-front was receding along this valley from south to north it held a lake from Manhattan island to Albany and Lake Champlain, until the farther glacial retreat allowed this long narrow lake to be mainly drained northward into the Champlain arm of the sea. In the Mississippi basin the northern subsidence probably produced broad shallow lakes along the border of the earlier ice-sheet, preventing the accumulation of terminal moraines and extending a mantle of loess over the till as the ice melted. Basins now draining northward, also, as of the Contoocook river in New Hampshire, the great lakes tributary to the Saint Lawrence, and the Red river of the North, held glacial lakes due to obstruction on the north by the ice-barrier. The old shore-lines of these glacial lakes are found to have now an ascent from south to north, caused by differential rise of the land after it was relieved from its load; and the successive beaches of Lake Agassiz, the largest of these lakes, which occupied the basin of the Red river and Lake Winnipeg, show that this upward movement was in progress simultaneously with the departure of the ice.

* C. H. Hitchcock, Geol. of Vt., vol. i, 1861, pp. 93–118. J. D. Dana, Trans. of the Conn. Acad. of Arts and Sciences, vol. ii, 1870, pp. 45–112; and many papers in this Journal, III, vols. i, ii, v, x–xiii, xv, xxii–xxvii, 1871–1884, etc. Warren Upham, Geol. of N. H., vol. iii, 1878, pp. 3–61; and this Journal, III, vol. xiv, pp. 459–470, Dec., 1877.

SUCCESSION OF EPOCHS, GLACIAL AND FLUVIAL DEPOSITS, AND

	EPOCHS.	EASTERN PROVINCES AND NEW ENGLAND.	MIDDLE AND SOUTHERN ATLANTIC STATES.
	RECENT OR TERRACE. (Mostly within the period of traditional and written history.)	Rise of the land to its present height, or somewhat higher, soon after the departure of the ice. Rivers eroding their glacial flood-plains, leaving remnants as terraces. Warmer climate than now, probably due to greater Gulf Stream, formerly permitted southern mollusks to extend to Gulf of St. Lawrence, now represented by isolated colonies.	Continued subsidence of coast at New York and southward, and rise of the mountainous belt, by displacement along the fall line of the rivers. Much erosion of the Columbia formation since culmination of second Glacial epoch; sedimentation in bays, sounds, and estuaries.
	CHAMPLAIN. (Close of the second Glacial epoch.)	Land depressed under ice-weight; glacial recession; continued deposition of upper till and deep flood-plains of gravel, sand and clay (modified drift). Terminal moraines marking pauses or re-advance during general retreat of ice. Marine submergence 150 to 230 feet on coast of Maine, 0 to 520 feet in Gulf and valley of St. Lawrence.	Less subsidence in latitude of New York and southward than at north; lower Hudson valley, and part of its present submarine continuation, above sea level. Gravel and sand deposits from englacial drift in Delaware and Susquehanna valleys, enclosing abundant human implements at Trenton, N. J.
GLACIAL PERIOD OR ICE AGE. PLEISTOCENE PERIOD.	SECOND GLACIAL.	Second great uplift of the land, 3,000 to 4,000 feet higher than now; snowfall again all the year; ice probably two miles thick on Laurentide highlands, and extending somewhat farther south here than in first glaciation. Lower till (ground moraine), and upper till (englacial drift). Terminal moraines, kames, osars, valley drift.	Renewal of great continental elevation (3,000 feet in latitude of New York and Philadelphia), of excessive snowfall and rains, and of widespread fluvial deposits, the Columbia formation, on the coastal plain, during early part of this epoch. Implements of man at Claymont, Delaware.
	INTER-GLACIAL. (Longest epoch of this era.)	Ice-sheet melted here; probably not more ice in Arctic regions than now. Fluvial and lacustrine deposits of this time, with those of the first Glacial epoch, were eroded by the second glaciation.	Depression, but generally not to the present level. Deep channels cut in the bed-rocks by the Delaware, Susquehanna, Potomac and other rivers. The Appomattox deposits much eroded. Relative length of this epoch made known by McGee from study of this region.
	FIRST GLACIAL.	Begun by high continental uplift, cool climate and snowfall throughout the year, producing ice-sheet. Much glacial erosion and transportation; till and stratified deposits. Ended by depression of land; return of warm climate, with rain; final melting of the ice. Isthmus of Panama probably submerged (Gulf Stream smaller), and again in second Glacial epoch.	Continental elevation; erosion of Delaware and Chesapeake bays, and of Albemarle and Pamlico sounds. Plentiful snowfall on the southern Appalachian mountains; snows melted in summer, and heavy rains, producing broad river-floods, with deposition of the Appomattox formation.

CHANGES IN ALTITUDE AND CLIMATE, DURING THE QUATERNARY ERA.

MISSISSIPPI BASIN AND NORTHWARD.	CORDILLERAN REGION.	EUROPE AND ASIA.
Terracing of river valleys. Northward rise of area of Lake Agassiz nearly complete before the ice was melted on the country crossed by Nelson river; but rise about Hudson bay is still going on. 7,000 to 8,000 years since ice-melting uncovered Niagara and falls of St. Anthony.	Including a stage of considerable uplift, with return of humid conditions, alpine glaciation (third Glacial epoch), and the second great rise of Lakes Bonneville and Lahontan. Very recent subsidence and change to present aridity.	Erosion and terracing of stratified drift in river valleys. Land passage of European flora to Greenland; succeeded by subsidence there, admitting warm currents to Arctic sea. Minor climatic changes, including a warmer stage than now. Upper and outer portions of Indo-Gangetic alluvial plain; extensive deposits of Hwang Ho, and destructive changes of its course.
Abundant deposition of englacial drift. Stone implements in river gravels of Ohio, Ind., and Minn. Laurentian lakes held at higher levels, and Lake Agassiz formed in Red river basin, by barrier of retreating ice, with outlets over lowest points of their present southern water-shed. Marine submergence 300 to 500 feet on southwest side of Hudson bay.	Depression probably almost to the present level. Restoration of arid climate; nearly or quite complete evaporation of Lakes Bonneville and Lahontan. Formation of the "adobe" continuing through the second Glacial, Champlain and Recent epochs.	Final departure of the ice-sheets; glacial rivers forming eskers and kames. Loess deposited while the region of the Alps was depressed lower than now. Upper (englacial) till, and asar, of Sweden. Marine submergence 500 to 600 feet in Scotland, Scandinavia, and Spitzbergen.
Ice-sheet here less extensive than in the first Glacial epoch, and not generally ice-bordered as then by lakes in valleys which now drain southward. Terminal moraines at extreme limit of the ice-advance, and at ten or more stages of halt or re-advance in its retreat.	Probable uplift 3,000 feet, shown by submerged valleys near Cape Mendocino. Second ice-sheet on British Columbia and Vancouver island; local glaciation of Rocky Mts., Cascade range, and Sierra Nevada, south to lat. 37°. First great rise of Lakes Bonneville and Lahontan.	Second elevation and general glaciation of northwestern Europe; the ice-sheets of Great Britain probably more extensive than in first Glacial epoch. Oscillations of ice-front; British Lower and Upper bowlder-clays, the Chalky, Purple and Hessle bowlder-clays. Terminal moraines in Germany.
Depression nearly to present level southward; more northward, but followed there by differential uplift of 800 or 1,000 feet. Great erosion of loess and other modified drift, and of "Orange Sand." Valleys of this epoch, partly filled with later till, are marked by chains of lakes in southern Minnesota.	Continental depression. Arid climate. Long continued denudation of the mountains; resulting very thick subaërial deposits of "adobe." Intermittent volcanic action in various parts of this region, throughout the Quaternary era to very recent times, and liable to break forth again.	Recession, or probably complete departure, of the ice-sheets. Land connection between Europe and Africa, permitting southern animals to extend far northward. Erosion of the Somme valley below its oldest implement-bearing gravels.
Pliocene elevation of continent brought to culmination at beginning of Quaternary era; this whole basin probably then uplifted 3,000 feet; excessive snowfall and rain; deposition of the "Orange Sand." Ice-sheet south to Cincinnati and St. Louis, at length depressing the earth's crust beneath it; slackened river floods and shallow lakes, forming the loess.	Latest rise (3,000 feet) of the Colorado Cañon district. Sierra Nevada and other Great Basin mountain ranges formed by immense uplifts, with faulting. California river-courses changed; human bones and implements in the old river gravels, lava-covered. Ice-sheet on British Columbia; local glaciers southward.	Uplift and glaciation of northwestern Europe; maximum elevation 2,500 feet or more (depth of the Skager Rack); France and Britain united with the Færöe islands, Iceland and Greenland. Uplifts of the Himalayas and other mountain ranges attendant on both Glacial epochs.

Not until the Quaternary era are certain proofs found of the appearance of man. During the earliest epoch of this era his implements and even his bones were entombed in the deep auriferous gravels of California, while great uplifts, with faulting and outflows of lava, were turning the rivers into new courses Stone implements have also been found in the much later Columbia formation in Delaware, which is here referred to the time of continental uplift at the beginning of the second Glacial epoch, and in the modified drift of Trenton, N. J., of southern Ohio and Indiana, and of central Minnesota, deposited during the stages of culmination and recession of the ice-sheet of that epoch. Nearly of the same age, probably, is the little image from an artesian boring through fluvial beds, which enclose a lava-sheet, at Nampa, Idaho; but the inhumation of the obsidian spear-head discovered by McGee in the upper sediments of Lake Lahontan belongs to a still later and indeed recent time.

The accompanying table presents a correlation of the successive Quaternary epochs and formations, in descending order from the present time to the beginning of this era, as reviewed in the preceding pages.

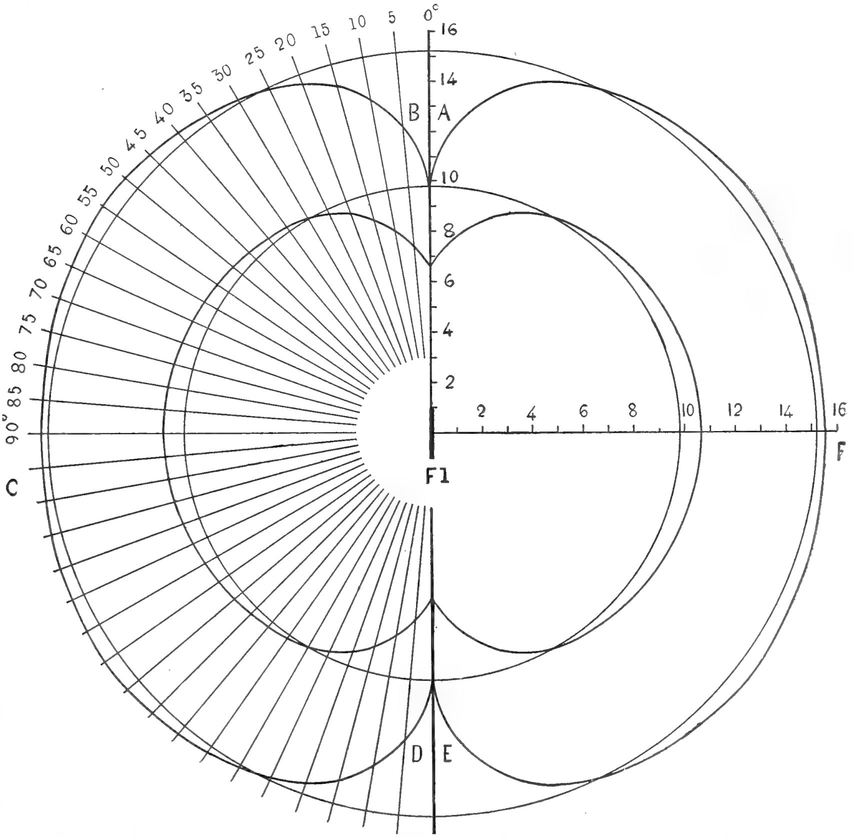
Art. VII.—*On the illuminating power of Flat Petroleum Flames in various azimuths;* by Alfred M. Mayer.

This paper contains the results of two series of measurements of the amount of light given out in various azimuths by two petroleum flames. One of these was the flat flame of a Hitchcock lamp in which the combustion is maintained by a blast of air driven against the flame by a fan moved by clock work. This flame is not surrounded by a chimney. The other flame was the flat flame of an ordinary petroleum lamp inclosed by a chimney.

The accompanying diagram expresses graphically the results of these experiments. The flat flame is shown by the thick line Fl. The polar coördinates of the closed curve A, B, C, D, E, F, give, by the aid of the scale of candle power Fl, A, or Fl, F, the amount of light given out by flame in various azimuths. The zero of angle is in the plane, A, E, of the flat flame. The inner and similar curve is the photometric curve of the flat flame of an ordinary petroleum lamp. The circles cutting these two curves are the photometric curves that would be given by the respective flames, if the light which each flame gives was equally distributed in all azimuths.

The following table gives the candle power of each flame at azimuths differing by 5°. The photometric measures are the mean of six series of experiments.

Azimuth.	Hitchcock flame.	Ordinary flame.	Azimuth.	Hitchcock flame.	Ordinary flame.
0	9·8	6·6	50	15·8	10·25
5	12·25	7·45	55	15·8	10·35
10	13·5	8·15	60	15·8	10·4
15	14·3	8·8	65	15·75	10·44
20	14·8	9·35	70	15·65	10·55
25	15·15	9·65	75	15·6	10·6
30	15·35	9·85	80	15·6	10·6
35	15·55	10·0	85	15·6	10·6
40	15·65	10·1	90	15·6	10·6
45	15·75	10·2			



The flame of the Hitchcock lamp gives 15·6 candle power in azimuth 90°, and only 9·8 candle in azimuth 0°; that is, the edge of the flame gives about 37 per cent less than the flat surface. The flat flame of the ordinary petroleum lamp gives

in azimuth 90°, 10·6 candles; in azimuth 0°, 6·6 candles of light; that is the edge of the flame gives about 38 per cent less light than that given by the side. The flame of the Hitchcock lamp and the flame of the ordinary petroleum lamp with chimney increase in candle power with the azimuth in different rates. The reason of this is that the glass chimney acts as a reflector and tends to equalize the illumination in different azimuths. The photometric curve of the Hitchcock flame cuts the circle of average illumination at $26\frac{3}{4}°$; the curve of the ordinary petroleum flame cuts its circle of average illumination at 30° of azimuth. A flat coal gas flame does not (to me) show any difference in candle power, when its edge or flat side is presented to the ordinary Bunsen photometer.

As to the cause of the absorption of light, or, of the opacity to light of a petroleum-flame I have no hypothesis to offer; nor have any of the experiments I have made on the absorption action of this flame given me any clue as to its cause. As a friend observed, all we can say is that the gas house does for the gas of the coal gas flame what the lamp does not do for the gas of its flame.

Stevens Institute of Technology, Hoboken, N. J.

Art. VIII.—*On the Physical Properties of Hard-Rubber, or Vulcanite;* by Alfred M. Mayer.

The discovery of the large coefficient of expansion of hard-rubber by Kohlrausch,* in 1873, and of its remarkable diathermancy by Bell,† in 1880, attracted the attention of physicists to this substance. In this paper I give additional and more minute experiments on the above mentioned and other properties of this substance ‡

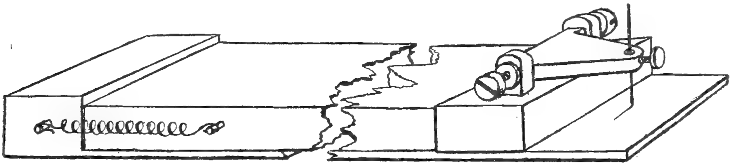
* Pogg. Ann., cxlix, 577, 1873. † This Journal, Oct. 1880.

‡ In his paper "On the Production and Reproduction of Sound by Light," this Journal, Oct. 1880, Mr. Bell gives, among other interesting experiments, those on vulcanite. A revolving disc, perforated with holes, produced rapidly recurring flashes of solar rays which impinged on selenium through which passed an electric current. In this circuit were two receiving telephones. The flashes of light caused synchronous alterations in the resistance of the selenium and in the electric current traversing it; so that when two receiving telephones, in the circuit, were placed to the ears a sound was perceived; the frequency of whose vibration corresponded to the frequency of the flashes of light. Mr. Bell writes: "We have made experiments with the object of ascertaining the nature of the rays that affect selenium. For this purpose we have placed in the path of an intermittent beam various absorbing substances. When a solution of alum, or bisulphide of carbon, is employed, the loudness of the sound produced is very slightly diminished, but a solution of iodine in bisulphide of carbon cuts off most, but not all, of the audible effect. Even an apparently opaque sheet of hard rubber does not entirely do this. This observation which was first made in Washington, D. C., by Mr.

Hard-rubber, vulcanite, or ebonite, as it is variously called, is formed of rubber and sulphur. These are combined in proportions of about two parts of rubber to one of sulphur. These ingredients, intimately mixed, are by the action of a temperature of 300° F., lasting three hours, converted into a black compound. The sun viewed through thin plates of this substance appears of a deep red color. The hard-rubber used in our experiments was formed of 64 parts of rubber of Para and 34 parts of sulphur.

The coefficient of linear expansion was obtained with the apparatus devised by me for this purpose and shown in the accompanying figure. A plate of steel one meter long and 6^{cm} broad had a lug of steel 15^{mm} broad screwed on to its end to act as an abutting piece against which the end of the bar of vulcanite, 96^{cm} long 6^{cm} broad and $1{\cdot}3^{cm}$ thick, was pressed by means of springs, as shown in figure 1. A block of steel,

1.



carrying a tracer, while bearing against the end of the bar of vulcanite was slid along the end of the bar and traced on the surface of the steel bar a very fine line. The bars are in a closed case in which they have remained for twenty-four hours. The temperature is taken from thermometers lying on the vulcanite bar. After having traced the line the apparatus is placed in a metal case surrounded by ice and after the temperature has become stationary another line is cut by the tracer. The bar in falling through the observed temperature has shortened by the distance between the lines less the shrinkage of the steel bar. The distance between the lines is measured by a micrometer microscope. As the tracer is of steel its con-

Tainter and myself, is so curious and suggestive that I give in full the arrangement for studying the effect. When a sheet of hard rubber, A, was held as shown in the diagram, the rotation of the disc or wheel B, interrupted what was an invisible beam, which passed over a space of several meters before it reached the lens C, which finally concentrated it upon the selenium cell D. *A faint but perfectly perceptible musical tone was heard from the telephone connected with the selenium* that could be interrupted at will by placing the hand in the path of the invisible beam. . . . . the effect is produced through two sheets of hard rubber having between them a saturated solution of alum. The anomalous behavior of the hard rubber alluded to above suggested the thought of listening to it also. This experiment was tried with extraordinary success. I held the sheet in close contact with my ear while a beam of intermittent light was focussed on it by means of a lens. A distinct musical note was immediately heard. We found the effect intensified by arranging the sheet of hard rubber as a diaphragm, and listening through a hearing tube."

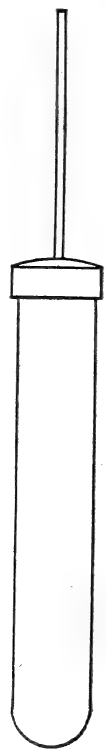
traction is the same as that of the steel bar on which it rests, so that we have only to consider the length of the steel plate equal to that of the vulcanite bar in computing the coefficient of expansion of the vulcanite. Calling this length l, the distance between the lines d, the coefficient of expansion of the steel k, and the coefficient of expansion of the vulcanite e, we have in the range of temperature t,

$$e = \frac{d \div l}{t} + k$$

The mean of twelve determinations thus made between 0° C. and 18° C. gave ·0000636 as the mean coefficient in the above range of temperature.

The formula of the cubical expansion of ebonite was determined by a mercurial thermometer made of a bulb of ebonite to which was attached a glass capillary tube of cylindrical bore, as shown in figure 2, the tube of vulcanite was placed in a metal shield to protect it from moisture and it and the glass tube surrounded with ice. The distance of the mercury from a fine line engraved on the glass tube was read with a cathetometer when the level of the mercury had become stationary, and the lengths between the line and the level of the mercury at different temperatures, obtained by heating the apparatus in a hot air chamber furnished with a thermostat, were measured. Knowing the capacity of the ebonite bulb and of a millimeter in length of the glass tube we obtained the rate of the apparent expansion, or rather, contraction of the mercury, from which, after having allowed for the expansion of the glass tube and the mercury in it, we deduced the absolute expansion of the vulcanite. The results of these experiments may be closely expressed in the following formula.

2.



$$V_t = V_0 + \cdot000182t + \cdot00000025t^2$$

The formula of the cubical expansion of mercury as given by Mendeleeff* is

$$V_t = V_0 + \cdot0001801t + \cdot00000002t^2$$

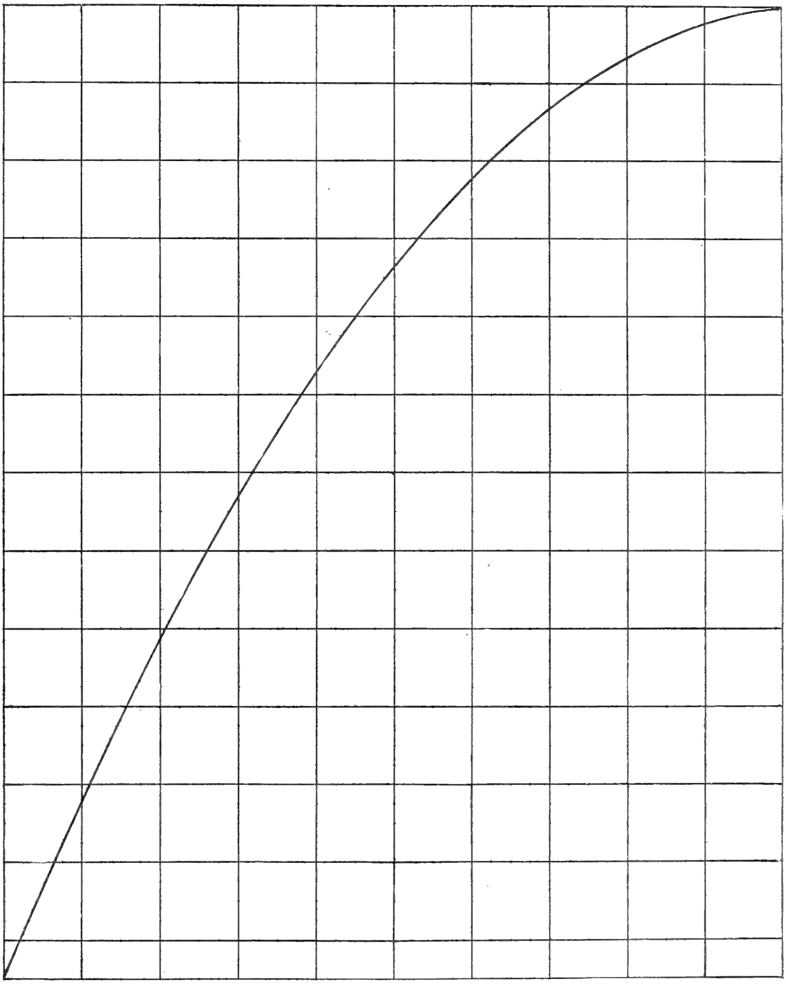
It is thus seen that the cubical expansion of vulcanite exceeds that of mercury so that the apparatus we have described may be used as a thermometer in which, as Kohlrausch observed, the scale will be inverted; when the temperature *rises*, the mercury in the stem *falls*.

The following table gives the volumes of vulcanite and of mercury at temperatures from 0° to 100°, as computed from the above formulæ. The difference, (in the fourth column),

*Jour. de Physique, v, p. 259.

which are all negative, show the increasing rate of expansion of the vulcanite over the mercury. These differences which form the apparent expansion (contraction) of the mercury in the ebonite thermometer are given in the accompanying curve, from which one may take the gradually increasing length of degrees on such a thermometric scale, which reads downward. The units of abscissæ, read from right to left, are 10° C., the units of ordinates, read downward, are each ·0002.

Fig. of Curve.



Temp.	Vol. of Mercury.	Vol. of Vulcanite.	Differences.
0°	1·000000	1·000000	·000000
10	1·001803	1·001845	·000042
20	1·003610	1·003740	·000130
30	1·005421	1·005685	·000264
40	1·007236	1·007680	·000444
50	1·009055	1·009725	·000670
60	1·010878	1·011820	.000942
70	1·012705	1·013965	·001260
80	1·014536	1·016160	·001624
90	1·016371	1·018405	·002034
100	1·018210	1·020700	·002490

As the apparent expansion of mercury in glass of a Fahr. thermometer is ·0000869 of its volume for 1°, and as the apparent contraction of mercury in a vulcanite thermometer is ·00249 from 32° to 212°, it follows that the length of scale from 32° to 212° on a vulcanite thermometer $=\frac{\cdot 00249}{\cdot 0000869}=28^{\circ}\cdot 6$ of length of scale on a similar mercurial thermometer of glass.

Kohlrausch states in his paper, cited above, that "the increase of the coefficient of expansion of ebonite with the temperature is very considerable. The linear expansion for the temperature t can be put

$$\cdot 000061 + \cdot 00000076\, t."$$

This formula agrees well with that which we determined for the cubical expansion. Further on he says: "The solid expansion of ebonite is, from the above numbers, at 0° equal to that of mercury; at higher temperatures it is still greater. It is possible that other kinds expand still more, so that as a curiosity a mercurial thermometer might be constructed whose readings sink on being heated. "The great expansion may possibly be connected with the proportion of sulphur which ebonite contains: Kopp (Pogg. Ann., vol. lxxxvi, p. 156) found for the coefficient of sulphur ·000061 at 30°. On the other hand, the contrast to soft caoutchouc is very remarkable. I will mention one fact which was observed in the observation of expansion. The bar of ebonite, which was about one centimeter in thickness, after being heated required a considerable time before it assumed a constant length. Although the bad conductivity is doubtless the principal cause of this, I imagine that another phenomenon is also at work. Like the elastic change of form, the expansion by heat may also not take place instantaneously, but continue itself after the change of temperature, gradually becoming weaker. A few observations of Matthiessen's with glass (Pogg. Ann., cxxviii, p. 521), seem to

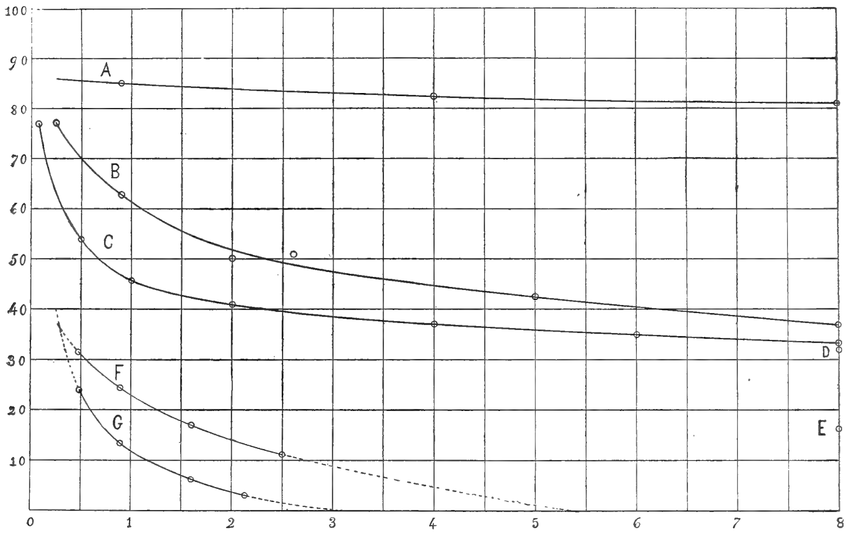
point in this direction; probably this thermal after action, like the elastic occurs in an eminent degree in organic substances."

The specific heat of vulcanite was determined by the method of mixtures. Small fragments of vulcanite were heated to near the temperature of boiling water in Regnault's apparatus and dropped into a water calorimeter. After corrections for equivalents in water of calorimeter and thermometer and for radiation and evaporation, three experiments gave these results:

1) ·33124 2) ·33077 3) ·33225 Mean = ·33125

On the diathermancy of vulcanite numerous careful experiments were made. The results of these and of experiments on other substances are given in the accompanying diagram of

4.



curves. In this diagram the figures on the axis of ordinates give percentages of heat effect on thermopile transmitted by plates of various substances whose thickness in millimeters is given by the figures on axis of abscissæ.

Curve A gives the heat effect of sun's rays transmitted by St. Gobain glass. The solar rays in these experiments and in those of F, G and E were reflected from a speculum-metal mirror of a heliostat.

Curve B shows the heat effect of rays from a Locatelli lamp transmitted by St. Gobain glass.

Curve C, the same as B as given by Melloni.

Curve F, the heat effect transmitted by sun's rays through vulcanite.

Curve G, the heat effect transmitted by sun's rays through vulcanite.

D is the percentage (32 per cent) of heat effect from a Locatelli lamp transmitted by a plate of obsidian 8^{mm} thick.

E is the percentage (16·5 per cent) of heat effect of sun's rays transmitted by a plate of obsidian 8^{mm} thick.

The examination of the curves F and G and of the points D and E shows that the rays transmitted by vulcanite and obsidian are of long wave-length; these are in greater percentage in the rays from the Locatelli lamp than in those from the sun. A plate of vulcanite one-half millimeter in thickness transmits 32 per cent of these rays while of the sun's rays 24 per cent are transmitted. The plate of obsidian of 8^{mm} thickness acts in like manner, but it screens even a greater proportion of the sun's rays than it does those from the Locatelli lamp.

In making the experiments on the transmission of the sun's rays I used a revolving diaphram pierced with holes of various diameters. The face of this diaphragm was exposed to the solar beam; sections of which, equal to the area of the different holes, were transmitted to the thermopile, which was placed at such distances from the diaphragm that the whole of the rays transmitted were included in the area of the face of the pile. The deflections of galvanometer produced by beams going through holes of different diameters are given below.

Diameter of hole.	Deflection.	Diameter of hole.	Deflection.
1) $1·25^{mm}$	8·5	3) $4·9^{mm}$	131·5
2) 3·4	63·0	4) 6·1	204 0

If the heat given to pile is as the area of the aperture, then the squares of the diameter of aperture divided by the deflections should equal a constant, as follows:

$$1)\ \frac{1·5625}{8·5} = ·1838 \qquad 3)\ \frac{24·01}{131·5} = ·1826$$

$$2)\ \frac{11·56}{63} = ·1835 \qquad 4)\ \frac{37·21}{20·4} = ·1824$$

Mean = ·18305

I mention these experiments because they show that such a diaphragm may be of service to those who wish to obtain in succession definite amounts of heat from a solar beam.

The index of refraction of vulcanite was measured by ascertaining, in a spectrometer, the angle of maximum polarization of a polished surface of vulcanite. The mean of fourteen measures gave for this angle 57° 29′, and the tan. 57° 29′ = 1·568 for the index of refraction; a number nearly as great as the index of refraction of flint glass.

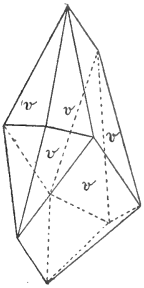
Thin lenses of vulcanite and of obsidian were made for me by Mr. John A. Brashear and with them I concentrated the rays of long wave-length to invisible foci on the face of the thermopile.

Stevens Institute of Technology, Hoboken, N. J.

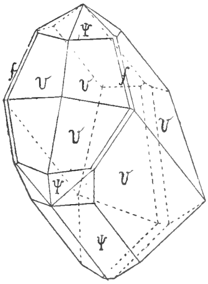
Art. IX.—*On some remarkably developed Calcite Crystals;* by Louis V. Pirsson.

Beautiful specimens of calcite are procured at Guanajuato in Mexico, and through the dealers have found their way into collections. On these specimens, not only are simple scalenohedrons of the ordinary form, $1^3(21\bar{3}1)$, common, often of great beauty in the perfection of their crystal form, but also twins, which are often developed in a most remarkable manner. As these, so far as can be learned, have never been described, it has been thought that an account of them with some figures, would not be without interest.

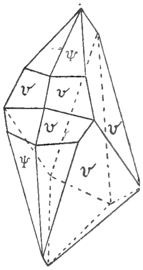
1.



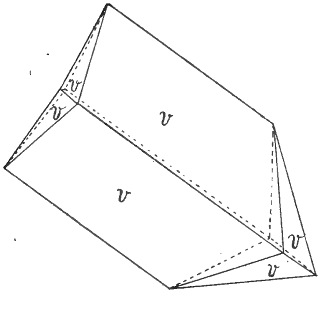
2.



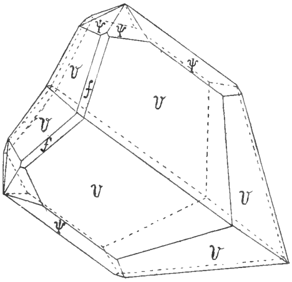
3.



1*a*.



2*a*.



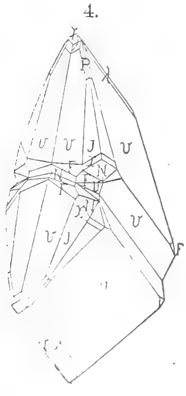
The twins consist in general of the ordinary 1^3 scalenohedron, twinned always upon $01\bar{1}2$, $-\frac{1}{2}$. By a development of two faces of the scalenohedron and the corresponding ones in twin position, the crystals are lengthened out into four sided prisms, with a re-entrant angle at one end and a salient angle at the other. They are usually attached to the rock at the salient angle with the prism projecting and at first sight present no appearance of hexagonal symmetry. They appear rather like twinned monoclinic crystals, consisting of a prism and pyramids, the latter forming the re-entrant angle at the end.

In fig. 1 the simplest and most common of these forms is shown; $v=1^3$ $(21\bar{3}1)$. In this figure the crystal is drawn in the usual position of the plus scalenohedron; in fig. 1*a* the same crystal is shown after a revolution of 60° into the position of a minus scalenohedron in order to better present the great development of four of the scalenohedron faces into a prism. This is the usual development of the greater number of specimens examined. The prism like form varies greatly in length with different crystals. These twins and simple individuals occur intimately associated together on the same specimen. Some twins are very large, up to eight or ten inches long. The larger crystals are however of the simple twinned form described, while the smaller ones are in general more highly modified. One of these is shown in fig. 2 in its normal position and in fig. 2*a* revolved, as in the previous example, 60° to show its prismatic development. On this crystal the forms *v*, 1^3, $(21\bar{3}1)$; Ψ, $\frac{1}{5}^{\frac{11}{3}}$, $(7\ 4\ \bar{1}\bar{1}\ 15)$; and *f*, -2 $(02\bar{2}1)$ were observed.

The most common habit of the smaller crystals is shown, however, in fig. 3, where of the scalenohedron, $\frac{1}{5}^{\frac{11}{3}}$ one pair of faces is represented, largely developed in front, cutting off the main form 1^3 above the re-entrant angle, while the other two pairs are either wholly wanting or are developed in so small a degree as to practically be so. It will be observed in the study of these crystals that all scalenohedral faces which appear as bevelments of the acute prism-like edge, must lie in the zone $10\bar{1}1 \wedge 01\bar{1}2$ and this affords an important aid in their identification. The crystal faces do not generally reflect light well but sufficiently so for fair measurements on the reflecting goniometer and the determination of the forms.

Fig. 4 represents a very remarkable calcite from the collection of Mr. Norman Spang, who very generously presented it to Professor Penfield and the latter has kindly allowed me to study and figure it in connection with these Mexican crystals. Mr. Spang obtained it in the southwest, but the exact locality could not be discovered. From its general similarity to the described forms, it will be suspected of having come from the Mexican locality. It differs from all of them which have been examined in being much more highly modified and especially by the presence of minus forms. The forms observed on this crystal were *r*, 1, $(10\bar{1}1)$; *v*, 1^3, $(21\bar{3}1)$; *F*, 2^3, $(24\bar{6}1)$; J $-\frac{4}{3}^{\frac{7}{3}}$, $(8\ 20\ \bar{2}\bar{8}\ 9)$; *P*, $-\frac{4}{5}^3$, $(4\ 8\ \bar{1}\bar{2}\ 5)$; *x*, -2^2, $(13\bar{4}1)$; N $-4^{\frac{5}{3}}$ $(4\ 16\ \bar{2}\bar{0}\ 3)$, and λ, 1^2, $(31\bar{4}2)$.

4.



While the planes of the plus forms were generally smooth and gave fair reflections of the signal, the minus forms were always striated, resulting from an oscillation of them with the main face $-\frac{4}{3}^{\frac{7}{3}}$. These striations were not however, as is often the case, mere lines blending the signals into an unbroken band of light, but were distinct facets, often of some size. As a result, each form gave a distinct reflection of the signal, by which it was possible to recognize and measure it with a fair degree of accuracy. The form $-\frac{4}{5}^{3}$ occurred as a distinct pair of faces at the top of the striations and by covering the latter with wax, the former could easily be measured with exactness. The striations of these minus forms were also all in one zone and this when determined aided greatly in their identification. Along the zone, the signal of each face stood out sharply in a dim band of light connecting them and pretty exact measurements could be made. The forms -2^{2} and $-4^{\frac{5}{3}}$ occurred most largely at the bottom and they are so represented in ideal symmetry in the figure. At the re-entrant angle, the main plus form v, 1^{3}, and the main minus form $\frac{4}{3}^{\frac{7}{3}}$, occurring in about equal development, the crystal presents at this end the appearance of the di-hexagonal pyramid.

The following table of measured and calculated angles is appended to show the identification of the forms.

Angles of Scalenohedrons.

	Long edge.		Short edge.		Middle edge.	
1^{3} $(21\bar{3}1)$	calc.	35° 35½′	calc.	75° 22½′	calc.	132° 58′
	meas.	35 49	meas.	75 24	meas.	133 05
		36 10		75 07		133 07
1^{2} $(31\bar{4}2)$	calc.	24 10			calc.	113 45
	meas.	24 13			meas.	113 26
						113 56
$\frac{1}{5}^{\frac{11}{3}}$ $(7\ 4\ \bar{11}\ 15)$	calc.	22 01	calc.	39 41		
	meas.	22 04	meas.	40 40		
		22 30				
2^{3} $(24\bar{6}1)$	calc.	37 30				
	meas.	37 00				
$-\frac{4}{5}^{3}$ $(4\ 8\ \bar{12}\ 5)$	calc.	34 20½	calc.	72 22		
	meas.	34 20	meas.	72 23		
		34 10				
	calc.	30 11½	calc.	81 16½	calc.	131 30
$-\frac{4}{3}^{\frac{7}{3}}$ $(8\ 20\ \bar{28}\ 9)$	meas.	30 01	meas.	81 02	meas.	131 29
		30 15		81 12		131 56
		30 11				
		30 18				
$-4^{\frac{5}{3}}$ $(4\ 16\ \bar{20}\ 3)$	calc.	21 29½				
	meas.	21 40				

And also the following angles:

		Calc.	Meas.		
$r \wedge v$	$10\bar{1}1 \wedge 12\bar{3}1$	29 01½	29° 01′	29°	29° 04′
$r \wedge r$	$10\bar{1}1 \wedge 0\bar{1}11$	74 55	74 58	75	75 03
$r \times \lambda$	$10\bar{1}1 \wedge 31\bar{4}2$	9° 25′	9 30	9 31′	9 35
$P \wedge x$	$(4\ 8\ \bar{1}\bar{2}\ 5 \times 13\bar{4}1)$	11 01½	10 50	11	11 19
$v \wedge P$	$(21\bar{3}1 \wedge 4\ 8\ \bar{1}\bar{2}\ 5)$	20 29	20 28	20 29	20 15
$v \wedge F$	$(21\bar{3}1 \wedge 24\bar{6}1)$	8 57	8 54		

In conclusion the author desires to express his thanks to Professor G. J. Brush, who kindly afforded the use of material from his collection and to Professor S. L. Penfield for valuable assistance and advice.

Mineralogical Laboratory,
Sheffield Scientific School, June, 1890.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *On a Relation between Capillary Phenomena and Molecular Mass.*—Goldstein has experimented upon the rise of aqueous solutions in capillary tubes and finds that in all or nearly all of the cases examined, there is a distinct relation between the molecular mass of the dissolved salt and the height to which the column of liquid rises. In his experiments, he operated in two ways. In the first, solutions were employed of such strength that the heights to which they rose in the capillary tubes were the same. In the second, the concentration of the solutions was the same and the ascent in the tubes different. Thus for example operating with 17·776 per cent solutions of the following substances, the heights obtained were as follows:

Substance.	Molecular mass.	Height.
NaBr	103	73·9
$CaCl_2$	183	73·4
$BaCl_2$	208	72·5
CaI_2	366	69.4

In the same tube, which had a radius of 0·1833 millimeter, water rose to the height of 80·57^{mm} at 22°. Since Mendeléeff has shown that the critical point of liquids can be calculated from the decrease of capillary height by changes of temperature, and since Schiff has observed a close relation between the boiling point of a liquid and its capillary constant, the author believes the laws of vapor pressures are the same as those governing the ascent of liquids in capillary tubes. The law of vapor pressure is represented by the expression $f-f'/f=kg$; in which f is the vapor pressure of the solvent, f' that of the solution, k a constant and g the mass of the dissolved substance. In like manner, Goldstein proposes the expression $H-h/HM=C$ to represent the capillary

phenomena, H representing the rise of water in the tube, h the rise of the solution, M the molecular mass of the dissolved substance and C a constant for the particular percentage of the salt used. Because salt-solutions do not follow the law of osmotic pressure, nor the laws of Wüllner and Raoult, the author multiplies the formula-values by Van't Hoff's coefficient i; and obtains for the final values of 10,000 $(H-h)i/HM$ the following numbers: $NaCl$ 13·35, KCl 13·24, $MgCl_2$ 13·26, $CaCl_2$ 13·36, $SrCl_2$ 13·78, $BaCl_2$ 13·77, $CoCl_2$ 13·95, $CdCl_2$ 13·87. The same result appears when certain data obtained by Valson with a five per cent solution are used to calculate the constant from the above formula. This conclusion is in accord with that of Traube.—*Zeitschr. Physikal. Chem.*, v, 233, Apr., 1890. G. F. B.

2. *On a Relation between Heat of Fusion and Solubility.*—In consequence of the striking analogy between the osmotic pressure of dissolved substances and ordinary gaseous pressure, an analogy to which attention was first called by Van't Hoff, reasoning before applicable only to gaseous substances may now be applied to solutions. WALKER has sought to combine the thermodynamical equation $D_T p = \rho / T o$ with the gas equation $pv = 2T$, now applicable to solutions; and thus to deduce a relation between the solubility of a substance in a given solvent and its heat of fusion. The resulting differential equation $dp/p = \rho\, dT/2T^2$ gives by integration, after multiplying by T, the expression

$$T \log p = -\frac{\rho}{2} + \left(\log p_0 + \frac{\rho}{2T_0}\right)T.$$

In these formulas, T is the absolute temperature, p the osmotic pressure in the saturated solution, v the volume of the solution and ρ the molecular heat of solution, assumed constant. Plotting the above equation with the values of $T \log p$ as ordinates and T as abscissas a straight line is obtained, the constant factor $\log p_0 + \rho/2T_0$ being the tangent of the angle which the line makes with the axis of abscissas. This angle may be fixed by determining the solubility of the substance at two different temperatures; so that when one of these temperatures is the fusing point, the equation is

$$\rho = 2T_0(\tan \alpha - \log p_0).$$

A similar equation may be written for the fused substance, in which however, the molecular heat of fusion must be added to the heat of solution; so that the total heat is $\rho + \sigma$ and the new equation is

$$\rho + \sigma = 2T_0\ (\tan \alpha' - \log p_0).$$

Subtracting from this the former equation, we have

$$\sigma = 2T_0(\tan \alpha' - \tan \alpha)$$

by means of which σ or the molecular heat of fusion may be calculated. The straight line obtained by plotting the new equa-

tion $T \log p' = -\frac{1}{2}(\rho+\sigma) + (\log p_0 + (\rho+\sigma/2T_0))T$, cuts the former one at a point corresponding to the temperature of fusion. The author has calculated the heat of fusion of paratoluidine by this formula from its solubility in water and finds it to be 44·5 calories per gram, while the value directly determined is 39 calories. From the solubility of water in ether, he obtains for the heat of fusion of ice 154 calories; whereas it is in fact only 80. But this result is based on the assumption that the molecule of the dissolved water is H_2O; so that if it be H_4O_2, the calculated value will become 77, which not only agrees quite well, but is in accord with the statement of Eykman that only half the normal depression of the freezing point is observed when water is dissolved in liquid paratoluidine.—*Zeitschr. physikal. Chem.*, v, 193; *J. Chem. Soc.*, lviii, 686, July, 1890. G. F. B.

3. *On the Relation of Cupric chloride solutions to Heat.*—From thermo-dynamical considerations it follows, as Le Chatelier and Van't Hoff have pointed out, that when the heat of solution of a substance in its almost saturated solution is negative, the solubility will increase with rise of temperature; while when it is positive the reverse will be the case. REICHER and VAN DEVENTER have tested this conclusion for cupric chloride $CuCl_2 . (H_2O)_2$; one of the few salts which dissolve in much water with evolution of heat, its temperature-coefficient of solubility being positive. Consequently a remarkable behavior should be observed with this salt with respect to the heat of solution in liquids of different concentration. The authors find as theory predicts, that in a saturated solution the heat of solution is negative. From thermochemical data given by Thomsen on the heat of dilution of solutions of cupric chloride joined to data of their own, the authors calculated that at 11° the heat of solution attains a maximum when the solvent has a strength of about 8 molecules of $CuCl_2 . (H_2O)_2$ to 198 molecules of water. At this concentration, therefore, the salt would be dissolved without any thermal effect whatever; and this, experiment shows to be the fact. When the concentration is about 18 molecules of the salt to 198 molecules of water, the heat of solution becomes negative. *Zeitschr. physikal Chem.*, v, 559; *J. Chem. Soc.*, lviii, 1206, Nov., 1890. G. F. B.

4. *On the Heat of Combustion of Nitrogenous Animal Products.*—By means of the calorimetric bomb, BERTHELOT and ANDRÉ have determined the heat of combustion of the chief nitrogenous constituents of animal tissues, the results of which determinations are given in the following table. In this table column 1 gives the value in water-gram-degrees for one gram of the substance at constant pressure, column 2 the value for the quantity of material containing one gram of carbon, column 3 the heat of combustion of one gram if the nitrogen is eliminated in the form of urea and column 4 the value for the quantity containing one gram of carbon, the nitrogen being eliminated as urea.

	1.	2.	3.	4.
Albumin	5690	10991	4857	9381
Blood fibrin	5532	10820	4586	8970
Muscular flesh	5731	10671	4749	8841
Hæmoglobin	5915	10617	4964	8902
Casein	5629	11080	4799	9580
Ossein	5414	10806	4544	8976
Chondrin (calf)	5346	10544	4506	8924
Vitellin	5784	11166	4954	8596
Yolk of egg	8124	12052	7704	11632
Vegetable fibrin	5836	10807	4986	9047
Crude gluten	5995	10878	5245	9338
Isinglass	5242	10800	4192	8640
Fibroin	5097	10599	4077	8479
Wool	5567	11099	4537	9009
Chitin	4655	9943	4235	9043
Tunicin	4163	9014	4063	8794

In a second table given in the memoir, the percentage composition of these substances is given. It appears from the data given, therefore, that the average heat of combustion of the food-albuminoids is about 5691 calories per gram, or 10870 calories for the quantity which contains one gram of carbon. The loss of heat resulting from the elimination of nitrogen in the form of urea is 16 per cent. The mean heat of combustion of the carbohydrates is 9470 calories for the quantity containing one gram of carbon, the heat for one gram varying with the hydration. This heat is about one-fifth greater than that of the carbon present, this reserve of energy being the source of the heat developed during many fermentations. In the case of fats the heat of combustion per gram of carbon is from 12200 to 12500 calories owing to their small percentage of oxygen. About one-sixth of the total possible heat of the albuminoids is not available since the nitrogen is eliminated as urea; but in the fats and carbohydrates all the heat of combustion is available.

In another paper, Berthelot and André have given the heat of combustion for several nitrogenous compounds derived from the albuminoids; this heat being determined by combustion in oxygen in the calorimetric bomb. Glycollamine yields 3133·6 calories per gram, alanine 4370·7, leucine 6526·1, asparagine 3396·8, aspartic acid 2911·1, tyrosine 5915·9, and hippuric acid 5659·3. If the total heat of combustion be compared with the heat of combustion when the nitrogen is eliminated in the form of urea—conditions closely resembling those of the living organism—it will be observed that the heat is very much less in the second case; indicating the important part played by urea in connection with animal heat. If the nitrogen is eliminated in the form of uric acid, the deficit is 115200 calories per 14 grams, or 122000 calories if the carbon dioxide is in solution. If the nitrogen is eliminated as hippuric acid the deficit per 14 grams is 1012900 calories. In the herbivora, compensation occurs in the liberation of free nitrogen in the intestines and so the thermal deficit is small.—*C. R.*, cx, 884, 925; *J. Chem. Soc.*, lviii, 936, 937, September, 1890. G. F. B.

5. *On the Action of Zinc on dilute Sulphuric acid.*—The curious intervention of a third substance in chemical reactions has long been noticed. In the absence of moisture, for example, phosphorus may be distilled unchanged in oxygen and in the absence of nitrous acid nitric acid has no action upon either silver or copper. From this stand-point, PULLINGER has studied the action of zinc upon sulphuric acid. The zinc was purified by three distillations in vacuo, in a tube of hard glass. The acid was purified by diluting with three times its mass of water and boiling for six hours in a flask provided with an inverted condenser. A sphere of this zinc 1·25 grams in mass, lost in this acid of specific gravity 1·179 only five milligrams in sixty minutes. The conclusions of the paper are as follows: (1) Pure zinc with a perfectly smooth surface is not acted on by dilute sulphuric acid which has been submitted to prolonged boiling; (2) pure zinc with a rough surface is readily acted upon, but in a less degree by acids which have been boiled than by those which have not; (3) oxidizing agents such as electrolyzed sulphuric acid, hydrogen peroxide and nitric acid, increase the rate of solution; (4) reducing agents such as hydriodic acid almost entirely prevent solution, those containing sulphur however, like sulphurous oxide, being without effect; (5) it is not improbable that when zinc with a rough surface dissolves in dilute sulphuric acid, persulphuric acid acting by its presence is the cause of the solution; and (6) in all probability *pure* dilute sulphuric acid at ordinary temperatures would be entirely without action on metallic zinc whether the surface of the metal were rough or smooth.—*J. Chem. Soc.*, lvii, 815, Sept., 1890. G. F. B.

6. *New Melting-point Apparatus.*—An improved melting-point apparatus has been devised by CHRISTOMANOS, consisting of a two-necked bottle containing mercury, which can be heated in an air-bath. Through one of the openings a thermometer passes and also a wire from a voltaic cell. Through the other passes the drawn out end of a glass funnel. The substance to be experimented upon is placed in this funnel in the fused state and allowed to solidify. The space above it is then filled with mercury and the funnel is introduced into the bottle. The second wire from the battery connects, through a vibrating bell, with the mercury in the funnel. Upon raising the temperature of the bottle to the fusing point of the substance, contact is established between the two portions of mercury and the bell is made to ring. The temperature of the mercury in the bottle is then noted.—*Ber. Berl. Chem. Ges.*, xxiii, 1093, April, 1890.

G. F. B.

7. *Chemistry, Organic and Inorganic.* By Charles Loudon Bloxam. 7th Edition, revised and edited by John Millar Thomson and Arthur G. Bloxam. 8vo, pp. xii, 799, Phila., 1890. (Blakiston).—To the special features which have made Bloxam's chemistry so well known among chemists, the present edition adds new matter in the organic part, such as Raoult's method for

molecular mass, and the investigation of Fischer and Tafel on sugars. Portions of the book have been re-written and the whole has been revised so as to bring it up to date.

8. *Electro-chemical Analysis.* By Edgar F. Smith, Ph.D. 12mo, pp. 116. Philadelphia, 1890. (Blakiston).—Dr. Smith has done the science of analytical chemistry a real service by the preparation of this little book. Thanks largely to his own work in this direction, electrolytic methods of separation are rapidly coming into use in the laboratory and by their accuracy of result and convenience of application are gradually replacing purely chemical methods. The chemical student therefore will be glad to welcome a manual in which the theory and practice of electro-chemical quantitative analysis are so well set forth.

9. *Sugar Analysis.* By Ferdinand G. Wiechmann, Ph.D., 12mo, pp. viii, 187. New York, 1890. (Wiley).—The author's aim in preparing this book has been to meet the needs not only of the sugar house but also of the technical school. In a concise form he has collected together the principles and practice of the art of sugar analysis based on the use of the polariscope. The methods of sampling, the preparation of the material for examination, the optical analysis, with and without inversion, etc., are clearly described. The book closes with nineteen valuable tables, given to facilitate the necessary calculations.

10. *Practical Inorganic Chemistry.* By Ebenezer J. Cox, F.C.S. 16mo, pp. 51. London, 1890. (Percival & Co.).—This is a brief elementary class book designed to furnish the necessary notes, reactions and analytical tables required by the beginner in practical inorganic chemistry, in the Science and Art department.

11. *Velocity of Sound at very Low Temperatures.*—A base line of 1,279 metres was accurately measured, and the interval determined between the flash of a gun at one end and the appearance of the sound wave at the other. The following results were obtained: where t is the temperature, x the number of observations, and v the corresponding velocity:

$t =$	$-10{\cdot}9$	$-25{\cdot}7$	$-37{\cdot}8$	$-45{\cdot}6$
x	53·	114·	164·	205·
v	326·1	317·1	309·7	305·6m.

The velocity diminishes therefore 0·603 meter for 1° C.—*Phil. Mag.*, p. 507, Dec., 1890.

12. *Wave-lengths of Electrical Oscillations.*—In repeating Hertz's work upon this subject, H. K. Waitz has arrived at the following conclusions.

(1.) A discharge of an inductive coil of a definite species excites oscillations of different wave-length which may extend over an interval of many octaves.

(2.) Among these oscillations there is one of greater intensity, the wave-length of which is determined by the dimensions of the conductors.

(3.) The electrical oscillations in or upon conductors change

their wave-lengths when the medium surrounding the conductor changes.—*Ann. der Physik.*, No. 11, 1890, p. 435. J. T.

13. *Heat of the Moon and the Stars.*—C. V. BOYS has used his radio-micrometer to detect the heat of the stars and the moon. Although the instrument was competent to detect the heat of a candle at a distance of 2·8 kilometers, an image of the brightest star produced by a silvered concave mirror of 16 inches aperture produced no sensible indication. The moon, however, gave large indications, and the author discusses the radiation from the moon by the method of curves. The radio-micrometer could detect $\frac{1}{150000}$ of the entire heat radiation from the moon.—*Proc. Roy. Soc. Lond.*, 47, p. 480–499, 1890. J. T.

14. *Foam.*—LORD RAYLEIGH in his investigation upon surface forces discusses the question of the formation of foam and concludes that a certain amount of impurity and want of cleanliness is necessary for the formation of foam. Foam cannot be formed in chemically clean substances. Calculation shows that the thickness of oil which is necessary to stop the movement of small pieces of camphor over a definite surface area of water amounts to only 1·5 millionths of a millimeter.—*Proc. Roy. Soc.*, 28, March, 1890. J. T.

15. *A photochronograph.*—M. MAREY attaches to one end of a long band or ribbon of sensitive film a band of black opaque paper and to the other end of this film a similar band of red paper. The film is then rolled upon a bobbin beginning with the end of the red band. This operation is conducted in the dark room. The bobbin can afterwards be taken into the light, being fully protected by the black and red bands of paper. When one wishes to take a number of photographs of a rapidly moving object, the bobbin is introduced into the photographic apparatus. One end of the band rolls upon an empty bobbin and at the end of the operation the film is protected by the band of red paper. While the portion that is not exposed to the light is still covered with the black band, one can thus readily distinguish between the portions of the bobbin that have been exposed to light. The apparatus makes it possible to take a number of images upon the same band and consequently to submit them all at once to the same developer.—*Comptes Rendus,* Nov. 2, 1890, p. 626. J. T.

16. *Photographic Sensitives.*—H. W. VOGEL discusses the question of the different sensitiveness of plate sensitized with eosine and erythrosine according to different methods. A solution of erythrosine in water shows an absorption band near E. A more concentrated solution gives a band fading into the blue. The addition of silver causes these bands to disappear and in their place appears between E and D a weaker band. These absorption bands are so decided that they afford a very sensitive means of deciding whether one is employing an eosine or a eosine silver plate.—*Beiblätter Ann. der Physik,* No. 10, 1890, p. 983. J. T.

II. Geology and Natural History.

1. *International Congress of Geologists.* — The Organizing Committee of the International Congress of Geologists met at the Institute of Technology in Boston, November 13th, 1890. Messrs. Chamberlin, Davis, Gilbert, Hall, Hague, Hitchcock, Powell, Newberry, Shaler, Stevenson, Winchell and Williams were present.

The Secretary reported the vote of the London Bureau regarding the change of place from Philadelphia to Washington. Thirty-six ballots were received, of these thirty-three were in favor of Washington. These represent the members from Great Britain, France, Germany, Australia, Austria, Belgium, Hungary, India, Italy, Portugal, Roumania, Russia, and the United States. No negative votes were received from countries outside America. The majority of the Bureau, as well as a majority of the American Committee, thus expressing their preference for Washington, it was voted to hold the next session of the International Congress of Geologists in Washington, during the week beginning with the last Wednesday (26th) of August next.

The vacancy in the Committee caused by the death of Mr. C. A. Ashburner, was filled by the election of Mr. S. F. Emmons, Washington, D. C. The Committee now consists of the following members: Messrs. Branner, Chamberlin, Cope, Dana, Dutton, Davis, Emmons, Frazer, Gilbert, Hall, Hague, Heilprin, Hitchcock, Sterry Hunt, Leidy, Lesley, LeConte, Marsh, Newberry, Powell, Proctor, Shaler, Stevenson, A. Winchell, Walcott, Whitfield, and H. S. Williams.

During this meeting vacancies were filled and the organization of the committee perfected, so that the present officers and subcommittees are as follows: *Chairman*, J. S. Newberry, New York City, *Vice-Chairman*, G. K. Gilbert, Washington, D. C.; *Secretaries*, H. S. Williams, Ithaca, N. Y., S. F. Emmons; *Acting Treasurer*, S. F. Emmons, Washington, D. C.

(1) A sub-committee on the *Scientific Programme:* J. W. Powell, *Chairman*, Washington, D. C., J. D. Dana, New Haven, Conn., T. C. Chamberlin, Madison, Wis.

(2) A sub-committee on *Longer Excursions:* Clarence Dutton, *Chairman*, Washington, D. C., N. S. Shaler, Cambridge, Mass., J. J. Stevenson, New York City.

(3) A nominating sub-committee to nominate officers for the Congress: J. J. Stevenson, *Chairman*, New York City, T. C. Chamberlin, Madison, Wis., Alex. Winchell, Ann Arbor, Mich.

The following resolutions were adopted:

That the secretaries be authorized to prepare a circular of information, stating the organization, the time of meeting, and such other information regarding the Congress as may be thought necessary, in English and in French, to be signed by the Chairman and the Secretaries, and distributed among those likely to be interested in this country and in foreign countries.

It was further *Resolved*, that the Secretary be authorized to communicate to the editors of the American Geologist and the American Journal of Science the results accomplished by the Committee at the present meeting.

And it was *Resolved*, that the Committee assess its members five dollars each for expenses.

2. (1) *New Types of Carboniferous Cockroaches from the Carboniferous Deposits of the United States;* (2) *New Carboniferous Myriapoda from Illinois;* (3) *Illustrations of the Carboniferous Arachnida of North America, of the orders Anthracomarti and Pedipalpi;* (4) *The Insects of the Triassic beds at Fairplay, Colorado;* by SAMUEL H. SCUDDER, Mem. Boston Soc. Nat. Hist., vol. iv, No. ix, pp. 401–472, pl. xxxi–xlii, September, 1890. —Few departments of paleontology have fallen so wholly into the hands of a single investigator as the American fossil arachnids, myriapods, and insects. The labors of Meek, Worthen, Dana and Dawson, from 1860 to 1865, really introduced the subject of the terrestrial arthropods in this country, and since that time Professor Scudder has been nearly the sole inquirer.

The present memoir is a continuation of previous descriptive papers, and adds a number of new and important species to the mylacridæ and myriapods, with a summation of the known American paleozoic species of the latter group. The portion treating of the Carboniferous arachnids contains descriptions, discussions and good figures of the Anthracomarti and Pedipalpi. The last paper of this memoir on Triassic insects of Colorado, possesses considerable geological interest. According to the author, it is the first attempt to determine the age of a series of beds from insect remains alone. From a study of the associated plants, the horizon was first referred to the Permian, but Professor Scudder has noted so many Mesozoic characters in the insect fauna that any other time reference would be incongruous. Similar paleontological contradictions have been encountered several times before, between the plants, invertebrates, and vertebrates, with the general result that the higher organisms are taken as the chronological standard. C. E. B.

3. *Bulletin from the Laboratories of Natural History of the State University of Iowa*, vol. ii, No. I, pp. 1–98, pl. x–xii, 1890. —The monograph of the Pselaphidæ of North America by Brendel and Wickham is brought to a completion, and also the memoir by Shimek on the Lœss and its fossils. Mr. Shimek concludes that during the formation of these deposits the summers were comparatively warm and the glaciers had retreated far to the north. The sedimentation was apparently at or near the surface, and produced through the agencies of numerous shallow ponds and sluggish streams, thereby accounting for the fineness of the material, the differences of level, and the preservation of extremely delicate land and freshwater mollusca with numerous local faunal differences. C. E. B.

4. I. *Ueber einige Lycopodiaceen aus der Steinkohlenformation;* II. *Die Graptolithen des K. Mineralogischen Museums in Dresden;* by Dr. H. B. GEINITZ.—Reports K. Min. Geol. u. Præ-hist. Mus. in Dresden. No. 9, pp. 1–33, with 3 plates, 1890. —A large species of *Halonia* (*H. Dittmarschi* Gn.) is described with notes and citations of other related forms. The second part besides being an account of a special collection, contains much valuable synonomy and a plate illustrating the principal species.

5. *Prodromus Faunæ Mediterraneæ sive Descriptio Animalium Maris Mediterranei incolarum, etc.;* by J. V. CARUS, vol. ii, pars ii, pp. 278–496. Stutgart, 1890.—This portion of the work finishes the Gastropoda, including the Heteropoda and Pteropoda. The whole of the Cephalopoda are described, and the Tunicata are carried nearly to completion.

6. *Minerals from Snake Hill, New Jersey.*—E. W. PERRY announces that he has found the following named minerals at Snake Hill, N. J., within the past three years: datolite, pectolite, laumontite, prehnite, apophyllite, natrolite, analcite, gmelinite, stilbite, heulandite, calcite. Of these the gmelinite and pectolite are in fine specimens, the former rivaling the Nova Scotia mineral. Snake Hill is an ejection of trap, surrounded by sandstone forming a distinct hill about 5 miles from Bergen Hill.

7. *The Silva of North America, by Professor* C. S. SARGENT, *illustrated from drawings by* C. E. FAXON.—Part I of this beautiful work appeared some weeks ago, being a folio of 120 pages, with 50 lithographic plates. The set is to be completed in twelve similar volumes, and will deservedly receive a place among botanical works of the very highest rank. While the care, accuracy, and breadth of experience, which are manifested in the descriptions, will render the *Silva* of great value to the professional botanist, the author has so skillfully avoided every unnecessary technicality of language that the text may be readily understood by any intelligent though unbotanical reader. The aim of the work is to give full descriptions and detailed illustrations of all trees, native or naturalized in North America, exclusive of Mexico. Although a number of works have been written on our North American forest trees, nearly all are at present long out of date, and each has been confined either to a limited area of the continent, or to definite groups in the botanical system. Nothing of so general a nature has yet appeared, and the present work supplies a long-felt need.

In a brief preface we learn something of the years of study which Professor Sargent has devoted to preparation for this gigantic undertaking. To insure greater accuracy, he has spared no endeavor to see in a living state every plant described, and in this has succeeded with surprisingly few exceptions. In the systematic arrangement of the orders and genera, Bentham and Hooker's *Genera Plantarum* has in general been followed. In the nomenclature adopted, the rules of priority have been scru-

pulously regarded. This involves in some cases changes which are certainly unfortunate, but are, as the author justly remarks, necessary, if anything like permanency in botanical nomenclature is ever to be reached. An instance of this is the discarding of the appropriate and well-established name *Magnolia grandiflora* for the less agreeable *M. foetida*. The volume before us contains descriptions of thirty-four species of trees, each illustrated by one or more plates showing foliage, flowers, and fruit. There is a very simple introductory key to the thirteen orders which are treated. The generic and specific descriptions are very full, and are enlivened by the introduction of many interesting facts regarding the habits, uses, medical properties, history, and even paleophytology of the trees described. We can hardly speak in too high terms of the plates. In conjunction with delicate outlining, Mr. Faxon has made frequent use of faint surface shading, a method rather unusual in botanic drawings, but here employed with remarkable success. The plates were lithographed in Paris under the direction of the noted botanical artist, M. Riocreux, and reflect much credit upon all who have engaged in their production. It is only to be regretted that a work of such merit is necessarily expensive, and can be possessed by comparatively few. On this account botanical institutions and reference libraries should, wherever possible, place the *Silva* within reach of students and readers. B. L. R.

8. *Recherches anatomiques sur les hybrides;* by M. MARCEL BRANDZA. (*Revue générale de botanique*, II, Nos. 22–23.)—The study of vegetable hybrids has heretofore been directed almost exclusively to their external characters, and to such of their qualities as appear to be of agricultural or horticultural importance. Some interesting points in their physiology have of course received attention, such for instance as the diminished fertility; and scattered references to their anatomy could undoubtedly be found. The article before us, however, represents the first attempt to subject a number of hybrids to extended anatomical investigation, with a view to discover the principles upon which the parent characters are combined in their tissues. The examples described are from the genera *Rosa*, *Sorbus*, *Marrubium*, *Medicago*, *Cornus*, and *Cirsium*. The author reaches the conclusion that in some hybrids the tissues show a juxtaposition, but not a mingling of particular characteristics of the parents. Thus in the stem of "*Marrubium Vaillantii*," a supposed hybrid of *Marrubium vulgare* and *Leonurus Cardiaca*, the arrangement of the collenchyma is closely like that of *Marrubium vulgare*, while the fibro-vascular bundles correspond in number and position to those of *Leonurus*, the parents differing conspicuously from each other in both tissues. In other hybrids the tissues possess in all characters an intermediate nature between the parents, as in *Medicago falcato-sativa*. In a third less satisfactory category of hybrids, of which the author gives *Cirsium arvense-lanceolatum* as an example, the tissues of some organs show the intermediate

nature, while in other parts of the plant a juxtaposition of special characters of the different parents may be detected.

While these are just the results which the morphological traits of hybrids would lead one to expect, they lose none of their interest on that account, and furthermore M. Brandza's studies leave no doubt that anatomical investigation can render important assistance to systematic botany in furnishing excellent collateral evidence in cases of puzzling and doubtful hybrids. B. L. R.

III. Astronomy.

1. *Catalogue of Radiant Points of Shooting Stars.*—In the Monthly Notices of the Royal Astronomical Society [vol. l, No. 7] Mr. Denning has given some of the results of his indefatigable observing during the last fourteen years. His observations were undertaken to ascertain the radiant points of the minor star-showers generally. He presents a catalogue of nine hundred and eighteen radiant points arranged according to date through the year. At the end of the paper is a list of 45 long enduring and apparently stationary radiant points of shooting stars. The individual observations of the meteors are not given, the number (9177) registered in the 1297¾ hours of observation furnishing an obvious reason.

The mean horary number of meteors seen was 8·3, but the number obtained from observations at Ashley Down, in the country, was 11·4, as compared with 8·2 in Bristol. The difference Mr. Denning attributes to the lights and smoke of the town.

From thirty-eight shooting stars doubly observed he obtained the average height at beginning 71·1 miles, and at end 48·2 miles. By a comparison of a large number of similar results obtained by others he deduced the average height of 683 meteors at beginning to be 76·4 miles, and of 756 meteors at end to be 50·8 miles. If fire-balls and shooting stars were taken separately he found the usual heights of fire-balls at disappearance to have been 30 miles, and of shooting stars to have been 54 miles.

The maximum number during the hours of the night were seen between 2 and 3 A. M., when the rate was about double that observed during the early evening hours. The observations were apparently made in the absence of the moon, and allowance was made in stating the hours of observing for time occupied in registering the observed tracks.

The mean hourly rate for the first six months of the year is 5·8 meteors, and for the last six months is 10·8.

The existence of radiants continuing unchanged for several weeks, and even months has been frequently asserted by Mr. Denning, and is here reaffirmed as a fact of observation. Such radiants are so at variance with received theories of meteors that evidence of their existence needs to be of more than usual positiveness in order to be accepted as conclusive. It is proper then to note that it is not the radiant itself that Mr. Denning

observed. He has given us his deductions from his observations, and not the observations themselves, for the place of a radiant cannot be directly observed. He should not be surprised if other persons do not therefore at once accept his important deductions as fully proven, and that they are waiting for additional evidence.

2. *Washington Observations for 1885*, Appendix I. Government Printing Office.—The report of Lieut. Winterhalter, who was sent to attend the astro-photographic congress in Paris, and to visit certain European observatories, constitutes the Appendix I to the volume of Observations of the U. S. N. Observatory for 1885.

3. *List of Observatories and Astronomers;* by A. LANCASTER. (3d ed.) Brussels, 1890.—In this third edition of Mr. Lancaster's exceedingly useful book, the position of the observatories and the names of the astronomers in the observatories are corrected to date. Special pains were taken by Mr. Lancaster to secure the most reliable data for the geographical positions.

4. *Astronomical Papers prepared for the use of the American Ephemeris and Nautical Almanac*, vol. iv, Washington, 1890.—Mr. HILL gives in this volume his new theory of Jupiter and Saturn, the labor upon which has covered a period of seven and a half years. The method of Hansen is the basis of the development by Mr. Hill, but the modifications of that method to meet the demands of the problem are very considerable, so that the expression "a new theory" is entirely appropriate.

5. *Publications of the Washburn Observatory;* vol. vi, parts 1 and 2. Madison, Wis., 1890.—Part 1 of this volume contains the meridian observations made by Miss Lamb and Mr. Updegraff in 1887. The second part contains observations of double stars made by the director of the observatory, Mr. G. C. Comstock. The observations were made with the fifteen and a half inch equatorial during the years 1887–9.

6. *Terrestrial Magnetism.*—In Bulletin No. 18, of the U. S. Expedition to West Africa, Prof. F. H. BIGELOW gives a summary of some preliminary results reached in an investigation of the variations of the elements of Terrestrial Magnetism, undertaken in connection with his work on the Solar Corona (see this Journal, Nov., 1890, p. 393). After alluding to the inadequacy of present theories to explain the facts observed, he adds that one cause of vital importance has been omitted from the elements of the problem, namely, the motion of the Earth as referred to the ether in its neighborhood, and he proposes to base an explanation of Terrestrial Magnetism upon the dynamic effects produced by the inductive action of the Earth in its motions of rotation and translation through fields of force. In a word, the Earth may be regarded as a cosmical dynamo. Whatever may be the real nature of the ether, it possesses the property of transmitting directed influences according to the laws of energy, which may be regarded as vector potentials of various types. But two of these directed fields of

force at the Earth are considered, both generated by the Sun, one of which may be called the radiant field and the other the coronal field. The radiant field is propagated in rectilinear lines, and has been ordinarily discussed as phenomena of the æther, called heat and light; hence its direction towards the Earth is in the plane of the ecliptic. A sympathetic study of the electro-magnetic theory of light, and the recent discoveries in electrical oscillations, naturally leads one to a belief in this view, which is here assumed. The coronal field has been shown by the author to be formed by the same forces that are exhibited in the Solar Corona, of which it is the invisible extension; hence, the second premise is that the coronal field is directed perpendicularly to the ecliptic in the neighborhood of the Earth. It may be shown that the relative intensities of these two fields can be discovered by a consideration of the observed movements of the magnetic needle.

The solution of the problem depends upon ascertaining the mutual action, at any station, of the distribution of magnetism referred to three poles, the permanent pole, the rotation pole, and the translation pole, the names being assigned from important characteristics. These poles change their relations in diurnal, annual, and secular periods, depending upon known astronomical laws; thus *the permanent* pole, or the pole of the permanent magnetism of the Earth in the same hemisphere as the station, wanders in a secular period of long duration in the Earth's crust, and also rotates daily about the Earth's axis. The *rotation* pole, or the pole of induced magnetism, resulting from the earth's rotation, is an instantaneous pole formed successively by induction, its direction being a few degrees from the Sun, and lying near the plane of the ecliptic. The *translation* pole, or the pole of magnetic induction, formed by the motion of the Earth in its orbit, lies nearly along the line of the orbit as it pierces the Earth, and is also instantaneous.

After a discussion of the mathematical analysis required to solve the problem, particularly as to the position of the three poles, the composition of the fields, etc., the author goes on to say that a complete study of this problem will lead to the formation of equations of condition from observations, which, when solved, will give completely the unknown quantities, namely, the constants employed and the forces of the two cosmical fields. These being obtained, we can return to the problems of solar physics with renewed data. Hence, the magnetic needle on the earth's surface will probably be added to the spectroscope, the polariscope, and the bolometer, as an instrument for studying the constitution of the sun.

Some conclusions drawn are thus stated: *Long periods.*—The variations of the intensity of action in the sun cause corresponding fluctuations in the fields of force, detected as the 56-year, the 11-year, or other periods; if sporadic, as terrestrial magnetic storms. Since the poles of the corona do not coincide with the axis of rotation of the sun, the coronal field of

force is made to assume variable relations to the earth in direction and intensity, which gives rise to the 26-day period. *Annual.*—The variation of the components of the fields of force, combined with the change of position of the three poles among themselves, and the velocity of the earth in its orbit, produces the annual period, also simultaneously appropriate to both hemispheres. *Diurnal.*—The position of any observing station is constant as referred to the permanent pole, and both the station and this pole glide past the two instantaneous poles each day, producing the diurnal eastward and westward elongations in the position of the needle.

The distribution of the elongations.—The two instantaneous poles are located in such positions as to confine the active movements of the needle to the morning, forenoon, and early afternoon hours, leaving it nearly quiescent during the night. The afternoon elongation occurs at any station during the same hour throughout the year, as the comparatively steady position of the rotation pole requires. The two morning elongations, which fluctuate through two or three hours, follow the change of position of the translation pole as it moves eastward and westward through an angle of 45°. The principal neutral line, occurring an hour or more before noon, is coincident with the retardation of phase of the rotation pole. That there should be three sharply-marked elongations, and one undefined in time, agrees with the composition of the forces emanating from one quadrant of the Earth.

The latitudes.—Near the rotation pole the distribution of potential is at a maximum, which diminishes by a function depending upon the angular distance from it; near the translation pole it is at a minimum, and increases with an approach to the permanent poles. The polar latitudes of the Earth therefore feel especially the influence of the translation pole, and have a single, strong maximum and minimum; the middle latitudes are subject to both the polar distributions; the equatorial latitudes come at one time under a northern and again under a southern resultant of component actions.

The opposite elongations of the North and South Hemispheres.—The north permanent pole is surrounded by a magnetic force of one name, and the southern pole by a force of the other name; the rotation pole and the translation pole have but one kind of magnetism about each of them, whether these forces are of the same sign or not, which, reaching over into the Northern and the Southern Hemispheres, simultaneously produce opposite motions of the respective needles.

The disturbances.—The magnetic inductive forces can be traced within the surface of the solid earth by laws similar to those employed in discussing the inductions within the atmosphere; and there is every reason to believe that these currents, in conjunction with the free electricity deposited in the atmosphere as an associated function, due to the air being an heterogeneous conductor,

and not changing all the magnetic forces into heat through natural decay, will go far to explain the phenomena of the spasmodic disturbances.

The aurora.—The atmosphere screens off only a part of the components resolved parallel to the earth's axis, so that we have a field of lines of induction which may be again resolved parallel to the axis of the permanent magnetism of the earth. The effect of these conditions is to gather up such lines of force around the poles, and they may produce a system of relations like those seen in the aurora. A test can be applied by measuring whether in inclination the upper parts of the auroral beams are bent more rapidly towards the poles than the theoretic lines of force produced under the laws of the magnetic potential will admit.

IV. Miscellaneous Scientific Intelligence.

1. *Mexican Meteorites.*—Mr. Fletcher of the British Museum has made and published in the Mineralogical Magazine an exhaustive study of the numerous Mexican meteoric irons. He has collected the original accounts relating to the numerous irons that have been brought from Mexico. The following are his conclusions respecting the dispersion of these iron masses over the several Mexican States:

"In each of the States of Zacatecas, Oaxaca and Guerrero, only a single mass of meteoric iron has been found, and there is absolutely nothing to suggest that they do not represent independent falls.

"In Sinaloa, likewise, only a single mass has been met with, and its characters have not been determined: a suggestion of a relationship with another group would rest on the slight fact that the site of an extremely large mass is in a straight line with two other sites where large masses are now lying.

"In San Luis Potosi two localities are recognized, but there is a strong probability that the Charcas mass, which has undoubtedly been transported to that town from a distance, was brought from the neighbourhood of Catorce: and, even if this was not the case, there is no evidence that the mineralogical characters are such as to render separate falls improbable.

"In Durango four or five distinct localities are known, but the characters of the only masses which have been examined point unmistakably to the falls of distant masses having been independent of each other.

"In Mexico there has undoubtedly been a large shower of limited dispersion in the Valley of Toluca: the three remaining masses from Mexico and Morelos have not been examined, and are very small and portable: even if they have not been transported, they may be found on examination to present characters which will differentiate them from the masses of the Toluca shower.

"From Coahuila many masses have been got, but it is extremely probable that all of them were brought from a single district of very small area: the two Nuevo Leon masses have never been examined and had obviously been transported, perhaps from Coahuila or San Luis Potosi.

"In Chihuahua three or four areas are represented: but of the masses found in that State only those of the Huejuquilla group have been examined, and that in a very incomplete way: the recognition of the singleness of the fall of the Huejuquilla group depends almost entirely on the general similarity of appearance of the large masses. If the masses really belong to a single fall, as the available information makes most probable, the maximum dispersion is now 66 miles: but one of the terminal masses, that of San Gregorio, is known to have been transported by the Spaniards on one occasion for $1\frac{1}{2}$ leagues, while according to a tradition current three centuries ago it had accompanied the Indians when they journeyed southward to take possession of that part of Mexico."

2. *Kilauea.*—A letter from Rev. E. P. Baker of Hilo, dated Nov. 5th, speaks of Dana Lake, or a lake occupying essentially its position west of the debris-cone in Halemaumau, as boiling violently all over its surface, so that no crust remains upon it. Jets consisting of successive clots of melted lava from three feet to six, ten and even twenty feet in height were in constant play over it. He had not seen the lake lava so hot at any time during the past ten years.

Mr. Maby, at the Volcano House, about two months previous had reported that on Sept. 9th all activity in Dana Lake ceased, and that there was an outbreak of lava in another place. But three days later, the lake was again active and four other spots in its vicinity had opened.

3. *University Studies;* Published by the University of Nebraska.—This third number of a new and important series consists of three papers: 1st, The determination of specific heat and of latent heat of vaporization with the vapor calorimeter, by H. N. Allen. 2d. The color vocabulary of children, by H. K. Wolfe. 3d. The development of the King's Peace and the English local Peace-Magistracy, by G. E. Howard.

4. *Gesammelte Mathematische Abhandlungen;* von H. A. Schwarz.—The very important Mathematical Contributions of Professor Schwarz during the past thirty years, have been republished in two handsome octavo volumes by Julius Springer of Berlin. The first of these volumes is devoted entirely to his discussions of surfaces of minimum extent. The second volume contains his various papers in Geometry, differential equations, and other branches of the Higher Analysis.

APPENDIX.

ART. X.—*A Horned Artiodactyle* (Protoceras celer) *from the Miocene;* by O. C. MARSH.

IT is an interesting fact, that while all existing mammals with horns in pairs are artiodactyles, and none of the recent perissodactyles are thus provided, the reverse of this was true among the early forms of these groups. The *Dinocerata* of the Eocene, a specialized order of ungulates, as well as some of the perissodactyles of both the Eocene and Miocene, had horns in pairs, while no horned artiodactyles have hitherto been known from either the Eocene or Miocene.

A fortunate discovery made during the past season, in the Miocene of South Dakota, proves, however, that before the close of this period, one artiodactyle, at least, was provided with a pair of horns. This animal was apparently a true ruminant, and nearly as large as a sheep. Only a single skull is known, and this, fortunately, is in good preservation, except the extremity in front, which is broken off and lost. In general form and proportions, this skull is of the ruminant type. Its most striking feature is a pair of small horn-cores, situated, not on the frontals, but, on the parietals, immediately behind the frontal suture. These prominences were thus placed directly over the cerebral hemispheres of the brain.

The frontal bones are very rugose on their upper surface, and this rugosity extends backward on the parietals, and to the summit of the horn-cores, as well as between the latter, and along the wide sagittal crest. The horn-cores are well separated from each other, and point upward, outward, and backward, overhanging somewhat the temporal fossæ. They are conical in form, with obtuse summits.

Between the orbits, the frontals are depressed, and marked by two deep grooves leading backward to the supra-orbital foramina. Behind these, halfway to the horn-cores, is a median prominence resembling in shape the corresponding elevation on the skull of the male giraffe. The brain cavity is unusually large for a Miocene mammal. The occiput is very narrow, indicating a small cerebellum, and the occipital crest is weak. The occipital surface slopes backward.

The facial region of the skull is narrow and elongate. On the outer surface of the maxillary, just above the antorbital foramen, there is a deep depression, which probably contained a gland. The usual ruminant fossa in front of the orbit appears to be wanting. The orbit is large, and completely closed behind by a strong bar of bone.

The dentition preserved is selenodont and brachyodont, with only three premolars and three molars. The first premolar is much compressed transversely, and has but a slight inner lobe. The second premolar is triangular in outline, the inner lobe being much more developed. The last premolar has this lobe expanded into a strong cusp, and the crown thus becomes broader than long. The true molars have two inner cusps, each with a basal ridge. The outer crescents have a median vertical ridge. The enamel of the molar series is more or less rugose. There was a wide diastema in front of the premolars.

The posterior nares are situated far forward, the anterior border being opposite to the posterior cusp of the second true molar. The glenoid facet is large and convex, but the post-glenoid process is quite small. The paroccipital processes were well developed, but there were apparently no auditory bullæ.

This skull when entire was about eight inches (200^{mm}) in length. The distance between the orbits across the frontals is about three inches (75^{mm}), and the distance between the summits of the horn-cores, about one and one-quarter inches (32^{mm}). The extent of the premolar and molar series is three and one-eighth inches (80^{mm}), and the width of the palate between the true molars is one and one-quarter inches (32^{mm}).

As the animal represented by this skull is very distinct from any hitherto described, the genus may be named *Protoceras*, in allusion to the early appearance of horns in this group. The species may be termed *Protoceras celer.* The characters now known suggest affinities with the giraffes, but indicate a distinct family, which may be called the *Protoceratidæ.*

The geological horizon is in the upper part of the Oreodon beds of the Miocene. For securing this important specimen, the writer is indebted to his able assistant, Mr. J. B. Hatcher, whose many discoveries in the West are well known.

New Haven, Conn., December 17, 1890.

REMOVAL.

ANNOUNCEMENT.—The encouragement we have received in New York during the past nine months has led us to the decision to concentrate our entire business in that city. It is our purpose to transfer our Philadelphia stock to New York immediately. We are pleased to announce that we have just secured a New Store, No. 733 Broadway, only three doors below our former location, in which we shall have more space than we have had in our Philadelphia and New York stores combined. The concentration of our entire business in the metropolis will give us readier access to the markets of the world and enable us to deliver minerals to our European customers with greater despatch and at less cost. We trust that with new fixtures, an increased corps of assistants, and a constantly enlarging stock and experience we may merit and receive an enlarged patronage. All correspondence after January 1st should be addressed to us at 733 *Broadway, New York.*

Another Collecting Trip.—The tremendous demands now being made upon us for minerals have compelled us to again start off one of the members of our firm on a collecting trip. Though Mr. Niven's last trip of nearly six months was but recently completed, he is again away visiting important localities in the far west and Mexico, and in another month we expect to announce many additions to our stock as the result of his trip.

Hauerite Crystals.—Every one has been sold

Chalcotrichite from Arizona.—Another superb lot has just come in. The best specimens are cheaper and incomparably more beautiful than the foreign. Prices, $3.50 to $10.00. A few very choice, small specimens may be had as low as $1.00. Of microscopic mounts at 25 cents each, our stock is unquestionably the finest in the world.

Dakota Calcites.—Two new shipments received during December. They are well worth 25 cents to $2.00.

Australian Opals.—Possibly the largest and finest specimen ever secured is now in stock, price, $500.00; other smaller ones, 50 cents to $20.00. The color is rich blue and green.

California Golds.—Two more fine ones, the best ($100.00) is sold. Another remains at $25.00 for a true connoisseur.

Many other important additions.—**Vanadinite, Wulfenite, Descloizite, Mexican Topaz, Hyalite, Cassiterite, Apophyllite, Calcite, Tridymite, Opals, Obsidian, Grossularite, etc., fibrous Chalcanthite, Smithsonite pseudomorphs, Marcasites, Chondrodites,** a lot of fine Jasperized Wood sections, a lot of rare Norway crystals including **Glaucodote, Aeschynite, Axinite, Monazite, Alvite, etc., Astrophyllite** in extra fine broad blades, etc.

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[THIRD SERIES.]

C.D. WALCOTT.

ART. XI.—*A Solution of the Aurora Problem;* by Prof. FRANK H. BIGELOW.

THE problem of the Aurora to which reference is made, is the question of the location in space of the visible arch and streamers, referred to the surface of the earth, as seen by an observer. This is becoming a matter of more importance than it once was, because the progress of discovery shows that it is one of the indices of the physical connection between the sun and the earth, as communicated through the medium of the ether. It therefore holds the same relative position that light and heat do to meteorological phenomena, or that induction does to magnetic variations. But it has the peculiarity of marking out the paths of the magnetic and electric forces that enter or depart from the earth, for it will be assumed that observations have already settled the fact that the auroral streamers coincide with the direction of the lines of force surrounding the earth, considered as a magnet. If there are any variations from this condition, it will be one of our ultimate objects to discover them, and perhaps the laws governing the same. At present, however, we limit ourselves to the simple case of the problem, namely the heights, and the distance of a ray from the observer. I am sorry to say that, so far as my knowledge extends, after a diligent search, there are no observations on record of the right form, that will enable me to test the theory. It is my object in this paper to explain the solution, and a simple piece of apparatus, in hopes that before long a suitable set of measurements may be made.

The methods of obtaining the heights of auroras hitherto given have afforded very discordant results, and a brief inspection shows that one or more terms of the problem have been assumed, which of course implies the discordant results mentioned. In my analysis there is one assumption at the beginning, but it is checked by the measurements, so that we resort in effect to a solution by trial and error. Auroral heights have been treated in several ways, (1) by parallax from two stations near the same meridian, the distance between the stations being known; (2) by observing a distinguishing point from two stations on different meridians, to determine the height and the azimuth of the point of vision; (3) by certain measures from one station; (4) by comparing with the height of neighboring objects. The results for height range from 75^{km} to 1600^{km}, in fact from the ground to the limits of the atmosphere. One general criticism applies to all these methods, that observers are not sure of seeing the same point continuously at one station, or of seeing the same point at all from different stations. M. Biese and M. Pétrélius, near Sodankylà, were stationed 4·5 miles apart in the same meridian, being connected by a telephone line. Having arranged to observe the same object simultaneously, Biese sent this message, "fix the line where the red ray is found;" at the other station no red ray could be seen.

Nordenskiöld's solution rests upon an hypothesis regarding the position of the center of the visible auroral circle above the surface of the earth. He measures the apparent altitude of the center of the arch (γ), the amplitude of the arch on the horizon (2β), and assumes the angle at the center of the earth between the station and the radius to the center of the visible circle. Hornstein assumes the angle at the center of the earth between the radius to one of two stations on the same meridian, and the radius extending to the point of measurement, which, as in the former case, is the same as assuming the distance from the observer to the given point. Newton assumes the distance from the observer to the center of curvature of the nearest part of the belt of the maximum number of auroras, which amounts to referring the phenomenon seen to the magnetic system of the earth. His solution relates only to the arches, but I shall show how with an assumption similar to his we may utilize the streamers, as distinguished from the arches, supposing those to lie in the lines of the magnetic field surrounding the earth.

The observations required consist in measuring the angle of inclination of a streamer to the vertical plane passing through the station, together with the azimuth of the ray, prolonged if necessary, at the point of its springing from the horizon. An

instrument can be readily constructed for this purpose. A horizontal circle for azimuth, levelled, the zero reading being set to the North geographic pole, carries a vertical arc graduated $\pm 90°$; the zero being at the top. At the center of this semicircle swings a bar having one edge straight, marked off with a linear scale. The sight line is on the diameter of the azimuth circle that pierces the center of the vertical semicircle, and may be simply a couple of diaphragms. The observation is made by turning the straight edge into such a position that it will lie parallel to the axis of a ray, or any other line to be measured, reading the top and bottom of the visible ray on the divisions of the linear scale, which gives the angular distance of the same from the point of disappearance of the ray as it passes the horizon; also reading the angle on the semicircle at which the arm is inclined from the vertical; and the azimuth on the horizontal circle of the point at which the ray touches the horizon. Such an observation can be made very quickly, even so as to take the rapid flashes of the vibrating auroras. The more inclined the rays from the vertical the more valuable the observation, and if the ends of the arch show streamers also visible at the horizon, they will be those especially desirable to secure.

1.

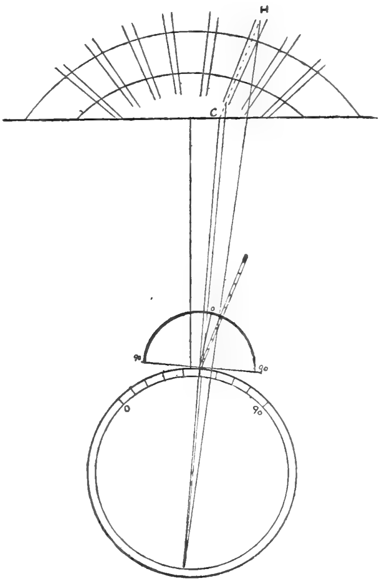


Fig. 1.—General plan of an apparatus for measuring the inclination of a ray to the vertical.

In the following solution we shall utilize the equation, cotan $l = 2\cot\theta = 2\tan m$, which was explained in my paper on the Corona (this Journal, Nov., 1890), the notation being, r, θ, the coördinates of any point on the curve whose equation is, $N = \frac{8\pi}{3} \cdot \frac{\text{Sin}^2\theta}{r}$; l the angle that the line of force makes with the radius to the point, and m the angle that the circle-tangent makes with the polar axis of reference. We take as the polar axis the radius that passes through the magnetic poles, which would be accurate if the potential were uniformly distributed in the earth considered as a magnet, but actually to that point of the surface to which the ray really belongs, as referred to

the existing non-homogeneous distribution. It may be hoped that an accumulation of the observations proposed will throw some light upon the pole of reference, as distinguished from the principal magnetic pole.

2.

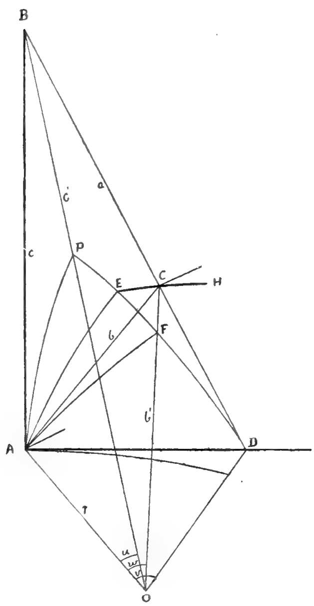


Fig. 2.—Showing the relation of a ray with respect to the horizon plane.

Pass a plane through the station of observation, tangent to the sphere at A, intersecting the magnetic pole of reference extended in B, and the aurora ray in C, the triangle A B C, being therefore in the tangent plane. Draw AD at right angles to AB. Now if planes be passed through these lines and the center of the sphere, the traces of intersection of the planes with the surface of the earth are as follows:

the trace of AB is AP,
" " DB " DP,
" " AC " AF.

Connect the center of the sphere with A, B, C and D; O C pierces the sphere at F.

Let the ray spring from the sphere at E, and reach the horizon plane at C, the visible portion being CH, upon which the measurements are made. Since a ray of given polar distance θ, has a given inclination to the perpendicular to the tangent plane at C, by measuring the angle and interpreting it as projected on a plane perpendicular to the line of vision AC, we have the means of describing its location in space. For of all the lines of force of similar reference that the line of vision passes, there is only *one* that can have the inclination due to a ray at the distance AC. This can be easily perceived by considering these lines around a sphere. Hence by standing at A the only question is how far along the line AC must one go to meet the ray whose angle, corrected for projection, will correspond with the one that is measured. The critical angle of our theorem is therefore at B, namely ABC, on the tangent plane, or the equivalent AOC, at the center of the sphere. If we assume AOC and compute thence to the measured angle, as will be explained, and find the values to be the equal, we have chosen the correct value of AOC. Thus by trial and error, may be found the true angle, and the distance of the point C from the observer.

Let $u =$ polar distance of station A to the pole P.
" $v =$ angular distance from station to the point D on the plane.
" $w =$ angular distance from station to the point C.
The ray lies in the plane, C, PEFD.
$AD = r \tan v$.
$AB = r \tan u$. $\tan B = \tan v \cot u$.
In the triangle ABC,
$A =$ the measured azimuth from magnetic meridian.
$c = AB = r \tan u$.
$B =$ the value obtained by assuming v.
Compute,
$b =$ distance of observer to base of ray on horizon.
$C = 180 - (A + B)$, which varies with v.
$b = c \sin B \operatorname{cosec} C = r \tan w$.
$OC = r \sec w$.
$FC = r \sec w - r = r(\sec w - 1)$, the height of C above the surface of the earth, measured along a radius.
At C this radius makes with the perpendicular to the plane, the angle w, lying in the vertical plane AOC.

Furthermore in the plane triangle BOC, we have,

$$OB = r \sec u = c',$$
$$OC = r \sec w = b'.$$

$BC = a$ may be computed from the formula,

$$a = \frac{c \,.\, \sin A}{\sin(A+B)}. \quad \text{Hence}$$

$$\tan \tfrac{1}{2}\theta' = \sqrt{\frac{(s-b')\,(s-c')}{s(s-a)}},$$ θ' being the angle BOC, or the magnetic polar distance of the point C on the ray.

Now we have by Gauss' Theorem,

$$2 \cot \theta' = \cot l,$$

where l is the angle that the ray at the point C makes with the radius of the earth to that point. This is the angle which is seen by the observer in its projected position.

If we assume the true length in space of the measured portion of the ray to be s, we have by fig. 3, the projections of s on the radius CK, and CI at right angles to the radius in the plane of the ray,

$$CK = s \cos l, \; CI = s \sin l.$$

The projection of CK on CN the normal to the plane, drawn at the point C, is $CM = s \cos l \cos w$; and of CI on CL perpendicular to CA, is $CL = s \sin l \sin(A+B)$. Therefore, representing by ΔA the difference in azimuth of the two points of the ray, and by Δh the difference in altitude of the same, we find,

$$s \sin l \sin(\mathrm{A}+\mathrm{B}) = \Delta \mathrm{A},$$
$$s \cos l \cos w = \Delta h,$$
$$\tan l \sin(\mathrm{A}+\mathrm{B}) \sec w = \frac{\Delta \mathrm{A}}{\Delta h}.$$

Since the left hand number of this equation is derived from theory, with the help of one assumed angle, and the right hand member comes from observation, we have a test of the correctness of our assumed angle. By trial and error, or using this as an equation of condition, we can arrive at the true angles involved.

3.

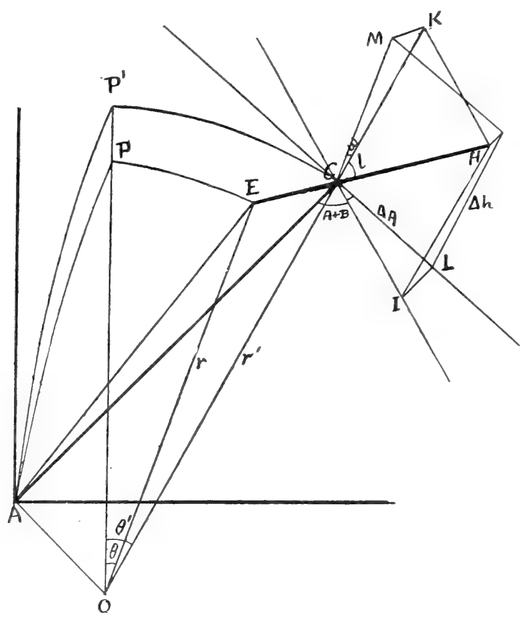


Fig. 3.—Showing the projection of the ray upon the reference plane.

We have now found the true value of r', θ', for a point C on the ray, and hence the order, N, is given by

$$\mathrm{N} = \frac{8\pi}{3} \cdot \frac{\sin^2\theta'}{r'}.$$

Then we may change from r' to $r = 1$, at the surface of the ground, and get the angular distance of θ from the magnetic pole, by

$$\sin^2\theta = \frac{3\mathrm{N}}{8\pi}.$$

For the height of C above the ground, we take $r' - r\cos(\theta' - \theta)$, measured on the radius r'.

I have used simply an orthogonal projection as the easiest to illustrate the theory, but obviously the vanishing point may be placed at A, and the necessary modification introduced into the formulæ. It may be remarked that since the visible distance of an aurora can be estimated within narrow limits, as it must be closely related to the latitude of the station, it will not be difficult to make the first assumption of the angle within easy range for computing. The change in the value of v is really a variation of the distance of the ray from the observer, and it is this quantity that has been so difficult to secure. Having once derived this distance correctly, a whole series of problems lie ready for discussion, as arising in meteorology and terrestrial magnetism.

I have shown in a recent paper that the coronal action of the sun arises from a potential of the magnetic type, and from magnetic observations it has been found that this influence is felt at the distance of the earth from the sun, as indicated by the responsive display of auroras after some outburst of the solar energy. It is to be hoped that this disturbance may be traced in the auroral lines, by their inductive displacement in the upper regions, though it may be too small a quantity to be detected by the observations. The whole subject of cosmical interaction of the sun and the earth, through the medium of the ether is so important, that this question of the aurora is one of vital significance, from its connection with it. I therefore venture to appeal to observers to make such observations of the auroral rays as I have indicated. My only apology for presenting the theory without experimental evidence is the fact that these measurements do not exist, although there is no reason to suppose they will be very difficult to make, and they will undoubtedly be interesting in future discussions of the subject:

Art. XII.—*Columbite and Tantalite from the Black Hills of South Dakota;* by W. P. Headden.*

1. Columbite.

The occurrence of columbite in the Black Hills was first noticed by Prof. W. P. Blake in 1884.† The localities then known were the Etta and Bob Ingersoll mines, in Pennington Co., S. D., and within a few miles of each other. Since that time the mineral has been found at a number of localities in

* The larger part of this article was read before the Colorado Scientific Society, Aug. 4th, 1890.

† This Journal, xxviii, 340, 1884.

the same county, and also in the Nigger Hill district in Lawrence Co. It is found with all of the stream tin, very sparingly, however, in that from Two Bit and Mace gulches in the Nigger Hill or northern district. Its presence with the stream tin suggests its possible association with the cassiterite in the veins whence the stream tin has been derived. This inference is only partially correct. The columbite is not always associated with the cassiterite, but I have found no columbite where cassiterite did not occur in the same vein—sometimes, but not always, intimately associated with it.

The chief occurrence of columbite in the Black Hills is at the Etta mine. It is abundant in the upper part of the open work on the southwestern and southern sides of the hill, where it occurs in a zone of beryl. In other parts of the mine it is associated with spodumene, feldspar, and sometimes quartz.

The line between the beryl and the tin ore, which in this case is a mixture of albite and muscovite, carrying an almost black cassiterite, is sharply defined. Sometimes there is an intervening band of pink feldspar, the mass of which is formed of radiating plates, and has a well defined but undulating and jagged upper boundary. This feldspar is probably an alteration product, as is suggested by its mode of occurrence and by the fact that the small spodumene crystals which occasionally occur in this association, have undergone complete change. The columbite occurring here is, in a general way, confined to the beryl, the crystals standing with one end upon or even penetrating the tin ore, while the crystals themselves are imbedded in the massive beryl. The individual crystals are comparatively small, crowded together, and often penetrate one another. This is not true, however, of other parts of the mine, where the crystals occur of larger size, but as isolated individuals or forming groups of a few crystals. The largest individual crystal in my possession weighs 14 pounds, and the largest group, consisting of two and a part of a third crystal, weighs $30\frac{1}{4}$ pounds.

The Peerless mine, about half a mile north of the Etta, has furnished but one or two larger aggregates of crystals and a few thin plates which occur in the interstices of the quartz masses. One of these larger masses was found on the surface, where the weathering away of the granite had probably left it.

The largest mass of which I have personal knowledge occurs in the Sarah mine, about one-quarter mile northwest of the Etta. The section of this mass as it is exposed is 8 in. × 14 in. I could obtain no information as to how much has already been removed, and there is no exposure showing how far the remnant extends into the enclosing rock mass. This is the only specimen which I could find in the mine; there is, however, not much work done at this point.

On the Newton lode it occurs very sparingly in thin plates, associated with beryl, which occurs disseminated through the granite in individual crystals from an inch to one and a half inches in diameter and several inches in length. Both the occurrence and the association of these minerals in the Newton lode are entirely different from that of the Etta mine.

The only piece of columbite found at the Bob Ingersoll mine has been described by Prof. W. P. Blake, who estimated its original weight to be 2,000 pounds. At the time of my visit to this locality only a small portion of this mass remained, it having been broken to pieces and carried away or cached. I obtained some smaller pieces, varying in weight up to thirty pounds; such a piece is now in the cabinet of the Dakota School of Mines. The mineral occurs in small crystals, and sparingly at the other localities which I have visited in the southern section, and the same may be said of the northern section of the Hills.

No measurements have been made on any of the crystals, and the description here given may need subsequent alteration. Well terminated crystals are rare and usually small. The best and indeed almost the only fair crystals obtained are from the beryl which occurs in the Etta mine, but I have in one specimen, from an unknown locality, two clusters of several crystals each, in which the crystals are well terminated.

The crystals occurring in the Etta mine vary greatly in luster, and also in their modifications. The usual form is tabular, the crystals being sometimes two inches wide, two or more inches long, and not exceeding one-quarter of an inch in thickness. The terminations of such crystals are always poor. The surfaces recognized on such are: 010, 110, 130, 100, 132, 102, 001, 031. These forms are not recognizable on all of the crystals; sometimes the prism 130, and sometimes both prisms are wanting. The crystals are often thinner at one edge than at the other, and are otherwise distorted; they are sometimes vertically, again irregularly, and even horizontally striated. The striæ on the Etta crystals do not appear to be due to polysynthetic crystallization. The luster on the different surfaces is not equally bright; that of the macropinacoid is almost always shining, while the basal pinacoid is very often dull, as though finely etched. In color the duller crystals are of a grayish black; the brighter ones of a pure black. The streak is, when not otherwise designated, a dark brown, and the powder, grayish black. The mineral from the Hills differs from specimens obtained from other sources in two respects: in fracture, which is rather fine-grained and quite dull in luster, while sub-conchoidal fracture and iridescence on fractured surfaces are almost wholly wanting.

The smaller crystals are more highly modified than the larger ones, as the following readings show. Both crystals here given are from the Etta mine. The forms observed are: 001, 061, 031, 032, 010, 110, 130, 100, 122, 132, 102, 131, 101(?), 111 (?). A fragment of a small and very bright crystal gave the following: 001, 031, 032, 010, one prism, probably 130, a brachy-pyramid 122(?), 102, 113. The larger crystals are much simpler, the usual forms being 001, 031, 010 and 100. The crystals from the unknown locality have a rather strong luster on all surfaces, and 010 is strongly striated, due to polysynthetic crystallization. The macrodomes are wanting, and the other surfaces are 110, 100, 162(?), 102, 131, 001. The crystals from the Advance claims have a different habit, being prismatic.

The occurrence of columbite in the northern Hills is confined, so far as known, to the stream-tin and to the three claims, the Centennial, the Uncle Sam and the Yolo. The crystals from the stream-tin are either tabular or stout prismatic in habit with quadrangular sections. Those from the Centennial claim are bright tabular crystals resembling those from the Etta mine; the few small crystals obtained from the Yolo claim show only the three pinacoids. The mineral is not abundant in this section, neither of those claims having furnished more than a few pounds of it.

My specimens from the stream-tin came from Mallory and Upper Bear gulches; for the former I am indebted to Mr. Mark Hydliff, for the latter to Capt. St. John, both of Bear Gulch. The columbite from Mallory Gulch and from the Yolo mine is different from that of the southern Hills, and also from that found on the Centennial claim. The latter occurs in an intimate mixture of albite and quartz, and forms black, shining tabular crystals, while the Yolo mineral occurs in irregular masses in a mixture of albite, quartz and muscovite. Its color is dark gray rather than black, and the small plates of mica adhere to it, forming a kind of coating. These masses and the only tabular crystals which I have definitely recognized, have been broken and the parts moved past one another; the parts correspond perfectly, and the space between them is filled indifferently with quartz, fine granular albite or mica, according to the nature of the adjacent mass, which shows the order of their separation and the igneous character of the vein.

Method of analysis.—The mineral was decomposed by fusion with potassic hydric sulphate, the fused mass powdered and boiled out with water, at least twice, and the mixed acids digested with ammonic sulphide to remove any stannic and tungstic oxides. I found Blomstrand's objection to fusion with sodic carbonate and sulphur, i. e., that some of the acids go into solution fully justified. The ferrous sulphide was dissolved

out with dilute sulphuric acid, the mixed acids were thoroughly washed and dissolved in hydrofluoric acid, the solution after the addition of a sufficient quantity—8 to 9-tenths gram—of potassic fluoride, was evaporated on a water bath until the residual mass was simply moist—it was not wet and also not perfectly dry ; for if evaporated to perfect dryness, even at the temperature of a water bath, the subsequent solution in water is apt to be turbid, due to the decomposition of the double fluoride. The moist mass was dissolved in the least possible quantity of boiling water, the solution concentrated a little on the water-bath, and then allowed to cool. The tantalic potassic fluoride will have separated, almost completely, by the time the solution has become cold. After standing for an hour or so the crystals of potassic tantalic fluoride are filtered off and washed with water acidulated with hydrofluoric acid and containing also a little potassic fluoride. The united filtrate and wash-water are again evaporated, when a small amount of the double salt will be obtained. This second crystallization should be examined under the microscope for the plates of potassic columbic fluoride, the appearance of which is a good indication that the solution has been sufficiently concentrated to allow of the complete separation of the potassic tantalic salt—a third evaporation is seldom necessary. I find this method for the separation of tantalic from columbic acid preferable to that proposed by Rammelsberg, i. e. to fuse with potassic fluoride.

The method as described yields clear solutions of small volume. The complete but not over-washing of the potassic tantalic fluoride is the most delicate manipulation in the process. The filtrate containing the columbic acid is evaporated on a water-bath, after the addition of 25–30 drops of concentrated sulphuric acid, so long as aqueous vapor is given off, when it is transferred to a sand bath and a part of the excessive sulphuric acid expelled, the columbic acid is subsequently thrown down by addition of a sufficient quantity of water and boiling. If the quantity of columbic acid present is large, it is better to add less sulphuric acid, about half so much, and a quantity of potassic hydric sulphate, evaporate to dryness and fuse the mass—the columbic acid obtained by boiling the fused-mass with water is more granular and filters better. The tantalic acid was invariably weighed as Ta_2O_5, after ignition in an atmosphere of ammonic carbonate. The analyses of my specimens presented no other difficulties.

The hardness of the specimens varied but little from 6, and the fracture as previously stated is uneven, with a tendency to fine granular rather than to sub-conchoidal. The sp. gr. and composition vary not only with locality but with the individual crystals from the same locality to such an extent that from an

analysis of one crystal, not even an approximate estimate can be made of the composition of an adjacent one.

Of the following analyses, I–VIII, were of specimens from the Etta mine.

Some notes about the individual specimens analyzed are here added:

I–VIII. *Etta Mine.*—I. The original large piece of rock, from which this specimen was broken, is now in the cabinet of the University of New York, and this, which is an older analysis, is given here because it is the only specimen having so low a specific gravity which I have found at this locality. The tantalic and columbic acid were separated in this analysis by fusing with caustic soda and subsequently treating the solution with carbon dioxide. IV. This was one of the group of three crystals weighing 30¼ lbs. V. A large individual crystal weighing 14 lbs., for which I am indebted to Dr. F. R. Carpenter. VI*a* and *b*. These are not duplicate analyses of the same piece, but of what I supposed to be distinct specimens. One analysis was made a year subsequent to the other. VII*a*. Crystal weighing about a pound, the smallest of the crystals forming the group, weighing 30¼ lbs. It seems to be intergrown with the other crystals at the base. VII*b*. Specimen found in the collection of the late Prof. Jansen, a fragment of a large crystal, showing the characteristics of the Etta mineral. VIII. The third crystal in the group of three before mentioned, shows but two pinacoids, 010 and 100. The upper portion of the crystal is broken off. For analysis of the other crystal see analysis Nos IV and VII*a*.

IX. *Peerless Mine.*—Fragments of a crystal from a mass of crystals found on the surface; occurrence similar to that at the Bob Ingersoll Mine.

X. *Cora Mine.* (?)—A large massive piece, free from rock having the appearance of having been broken out of a larger piece. It was obtained from Mrs. Wm. Franklyn. While this specimen is from another locality, and has different physical properties from the preceding it has the same molecular ratio.

XI. *Peerless Mine.*—Part of the second mass found in the mine, analysis No. IX was of the first piece found. They resemble one another more in composition than in physical properties.

XII. *Bob Ingersoll Mine.*—From the mass originally described by Professor W. P. Blake. The fragments show that this was a large aggregate of crystals; one piece showed a crystal with fair terminal surfaces.

XIII. *Sarah Mine.*—From the large mass described on page 90. This and the specimen from the Cora are the

only samples which are not unquestionably crystallized; it may have been a very large crystal; but it is not an aggregate of crystals as was the mass from the Bob Ingersoll.

	I.	II.	III.	IV.	V.	VI*a*.	VI*b*.	VII*a*.	VII*b*.	VIII.
Sp. grav.	5 890	6·181	6·245	6·376	6·515	6·612	-----	-----	6·707	6·750
Cb_2O_5	54·09	47·05	46·59	40·37	39 94	35·11	35·17	31·80	31·31	29·78
Ta_2O_5	18·20	34·04	35·14	41·14	42 96	47·11	47·08	52·14	52·49	53·28
SnO_2	·10	0·30	0·18	0·13	tr.	0·35	0·37	0·10	0·09	0·13
FeO	11·21	11·15	7·44	8·28	8·59	8·37	8·38	6·00	6·10	6·11
MnO	7·07	7·80	10·94	9·09	8 82	9·26	9·02	10·7	110·71	10·40
CaO	·21	-----	-----	*0·88	-----	-----	-----	tr.	-----	-----
	100 88	100·33	100·29	99·89	100·31	100·20	100·02	100·75	100·70	99·78
Atom. equiv.										
Cb_2O_5	47·82	35·12	34·80	30·12	29·80	26·16	26·25	23·73	23·37	22·22
Ta_2O_5	8·19	15·33	15·83	18·53	19·35	21·62	21·20	23·48	23·64	24·00
SnO_2	-----	0·21	0·13	0·09	-----	0·20	0·20	0·06	0·06	0·09
	56·01	50·66	50·76	48·74	49·15	47·88	47·65	47·27	47·07	46·31
FeO	15·57	15·48	10·30	11·50	11·93	11·62	11·64	8·33	8·47	8·48
MnO	9·96	10·96	15·40	12·80	12·33	13·20	12·70	15·08	15·08	14·75
	25·53	26·44	25·70	24·30	24·26	24·82	24·34	23·41	23·55	23·23
Atom. ratios.										
Cb : Ta=	6 : 1	7 : 3	7 : 3	5 : 3	3 : 2	5 : 4		1 : 1		1:1·08
Fe : Mn=	8 : 5	3 : 2	2 :3	1 : 1	1 : 1	1 : 1		3 : 5		4 : 7

* ·10 MgO.

XIV. *Locality unknown.*—This crystal was black, shining, vertically striated, tabular in habit, with 010 somewhat curved due apparently, to the successive deposition of thin plate-like individuals, each a little narrower than the preceding one—this cause will also explain the striation in this particular case.

XV. *Mallory Gulch.*—Nigger Hill District. Material was furnished me by Mr. Mark Hydliff, its color, streak and powder were light-brown; hardness inferior to that of the columbite from the veins; mass much cracked and inclosing mica. Analysis XV*b* gives the result after treatment with HCl. XVI. Same source, more compact but otherwise same as preceding.

Analyses XIV, XV, XVI, agree in giving the following approximate molecular formula.

$$3RCb_2O_6+2RTa_2O_6,\text{ with }R=Fe_{\frac{1}{2}}Mn_{\frac{1}{2}}.$$

These specimens have already undergone some alteration indicated by the presence of lime, magnesia and ferric oxide soluble in hot dilute hydrochloric acid. The low ratio of the acids to the bases is probably due to this cause. A similar

fact has been observed in regard to the stream tin, i. e. that it is richer in iron than the cassiterite from the adjoining lodes.

XVII. *Yolo Mine.*—Nigger Hill District My attention was called to this occurrence of columbite by Capt. St. John. owner of the property who also furnished me my best specimens of the mineral. This is different from any specimen yet described. It is fine-grained, gray-black in color, and the small irregular masses are penetrated by seams of mica and coated with scales of the same. It is the only specimen in which I have detected any admixed cassiterite. From analysis XVII*a*, 4·46 per cent, and from *b*, 4·64 per cent have been deducted. The high percentage of tantalic acid indicates that this mineral is rather a tantalite than a columbite; on the other hand the few small crystals obtained from this locality have the form and habit of columbite and if this observation is correct, the mineral should be classified as columbite.

The three following analyses are introduced here, partly for their own sake and partly for comparison.

XVIII. *Turkey Creek*, near Morrison, Colorado. Specimen furnished by Mr. Richard Pearce of Denver. It occurred as plates packed close together and enclosed between them was some pinkish feldspar, it is stained with a thin yellow ochreous incrustation.

XIX. *Haddam, Conn*—Specimen bought of Messrs. Geo. C. English & Co., Phila. Color black, luster sub-metallic rather shining, fracture sub-conchoidal with slight iridescence on fracture surfaces. Easily distinguishable from the Black Hills mineral.

XX. *Mitchell Co., N. C.*—Specimen bought of Dr. A. E. Foote, Phila., it resembles the Haddam mineral but is not so compact.

The first eight specimens are all from the Etta mine and are arranged (p. 95) in the order of their specific gravities. It will be seen that the amount of tantalate increases with the specific gravity and emphasizes the fact that these various isomorphous mixtures not only occur at the same locality but may even form the individual members of groups of crystals. They all have the habit and form of columbite, but the ratio of Cb : Ta gradually falls from 6 : 1 to 1 : 1, and in the case of the Yolo mineral becomes 1 : $1\frac{1}{4}$. If we examine the ratios afforded by the two specimens of Broddbo tantalite analyzed by Professor Rammelsberg we find in one case the ratio of Cb : Ta=1 : 1, in the other 3 : 2. Professor Dana says of the columbite from Northfield, Mass., analyzed by W. J. Comstock (Appendix III, page 30), "The Northfield mineral had the form and habit of ordinary columbite though it is essentially a tantalite. This was also true of the Branchville (Conn.) mineral . . . ." The

	IX.	X.	XI.	XII*a*.	XII*b*.	XIII.	XIV.
Sp. grav.	6·373	6·393	6·445	5·901		5·804	6·565
Cb_2O_5	37·29	37·91	40·28	80·98	57·32	61·72	40·07
Ta_2O_5	44·87	44·55	42·09		23·43	18·93	42·92
SnO_2	0·09	0·09	0·19	0·09	0·09	0·25	0·20
FeO	6·87	6·70	6·70	6·18	6·29	11·21	9·73
MnO	11·02	11·05	11·23	13·42	13·55	8·67	7·24
CaO	----	*tr.*	----	----	----	----	----
	100·14	100·30	100·49	100·67	100·68	100·79	100·16
Atom. equiv.							
Cb_2O_5	27·83	28·30	30·06	----	42·80	46·07	29·90
Ta_2O_5	20·21	20·07	19·00	----	12·80	8·53	19·34
SnO_2	0 06	0·06	0·13	----	0·06	0·17	0·13
	48·10	48·43	49·19	----	55·66	54·77	49·37
FeO	9·54	9·30	9·30	----	8·80	15·77	13·50
MnO	15·52	15·56	15·85	----	19.00	11·92	10·20
	25·06	24·86	25·15	----	27·80	27·49	23·70
Atom. ratios.							
Cb : Ta	2·78 : 2	2·83 : 2	3 : 2	----	7 : 2	11 : 2	3 : 2
Fe : Mn	3 : 5	3 : 5	3 : 5	----	1 : 2	3 : 2	3 : 2

	XV*a*.	XV*b*.	XVI.	XVII*a*.	XVII*b*.	XVIII.	XIX.	XX.
Sp. grav.	6·232		6·469	6·592		5·383	5·780	
Cb_2O_5	41·69	40·48	37·28	24·40	25·01	73·45	60·52	70·98
Ta_2O_5	40·19	40·97	44·48	57·60	56·82	2·74	19·71	9·27
SnO_2	0·11	0·15	0·16	0·41	0·31	1·35[a]	0·09	0·17
FeO	9·88	9·95	9·29	14·46	14·03	11·32	12·64	12·21
MnO	8·70	9·03	8·68	2·55	2·58	9·70	7·51	7·30
CaO	----	----	----	0·73	0·79	0·61	*tr.*	0·80
	100 67	100·58	99·89	100·15	99·54		100·47	100·73
Atom. equiv.								
Cb_2O_5	31·11	30·20	27·82	18·34	18·88	55·00	45·16	52·97
Ta_2O_5	18·10	18·46	20·00	25·95	25·60	0·30	8·88	4·17
SnO_2	0·06	0·10	0·10	0·31	0·20	0·64[b]	0·06	0·11
	49·27	48·76	47·92	44·60	44·68	55·94	54·10	57·25
FeO	13·72	13·82	12·90	20·30	19·46	15·70	17·55	16·96
MnO	12·44	12·72	12·22	3·60	3·65	13·40	10·57	10·30
								CaO 1·35
	26·16	26·54	25·12	23·90	23·11	29·10	28·12	28·61
Atom. ratios.								
Cb : Ta			7 : 5	4 : 5		1 : 0	5 : 1	13 : 1
Fe : Mn			1 : 1	5 : 1		8 : 7	1·75:1	8 : 5

[a] Incl. WO_3 1·14. [b] Incl. WO_3 0·50.

analysis of the Northfield mineral gives $1:1\frac{1}{4}$ as the ratio of Cb : Ta, while that of the Branchville mineral by the same analyst gives 1 : 1 for the ratio. It will be noticed that of the twenty specimens from different localities in the Black Hills, seven of them contain the Cb and Ta in the ratio of 3 : 2, four contain them in the ratio of 1 : 1 and one contains them in the ratio of $1:1\frac{1}{4}$. There is no doubt as to the form of these specimens unless it be in regard to the last, but in the case of the Northfield mineral, which gives the same ratio, i. e. $1:1\frac{1}{4}$, Professor Dana expresses no doubt. The tantalite from Yancey Co., N. C., analyzed by Comstock (Appendix III, p. 118), gives the formula $6RTa_2O_6+4RCb_2O_6$, while the columbite from Northfield, Mass, and the Yolo Mine, Lawrence Co., S. D., give the formula $5RTa_2O_6+4RCb_2O_6$. If the Broddbo and Yancey Co., N. C., specimens are real tantalites and the Northfield and Yolo minerals real columbites, there is an overlapping of specific gravity and chemical composition which destroys their value as guides in determining these minerals when the columbite and tantalite molecules are nearly equal in number. It was my intention to carry my work further and endeavor to show that there is chemically no sharp line between them, but that the tantalate may predominate in a true columbite to even a greater extent than is indicated by any of the analyses. In form the columbite is not always tabular or square prismatic in habit; the pinacoids to which these habits are due are sometimes very subordinate and the columbite becomes as pronouncedly prismatic as tantalite. I have so far been unable to determine the superior limit of tantalic acid compatible with the columbite form.

The Turkey Creek (Colorado) mineral, deserves mention as being an almost typical columbite, but is, like the greater number of the Dakota columbites, rich in manganese. It is also rather remarkable that it is the only one which contains tungstic acid. A pure ferriferous columbite has not yet been found in the Black Hills, the only specimen approaching it is that from the Yolo Mine which contains the Fe and Mn in the ratio of 5 : 1; by far the greater number of all the others are rather manganiferous than ferriferous columbites, this is in marked contrast to the tantalites, analyses of which are given later.

2. Tantalite.

Professor Schaeffer published in the Transactions of the American Institute of Mining Engineers, vol. viii, page 233, the identification of a mineral from the Etta Mine as tantalite and gives the following analysis: Ta_2O_5 79·01, SnO_2 0·39, FeO 8·33, MnO 12·13=99·86, sp. gr. 7·72. I have good reasons for believing that Professor Schaeffer's material was from the

Etta Mine, but I have not been fortunate enough to find any tantalite at this locality, and Professor Schaeffer's analysis does not justify his identification. Professor Schaeffer states that he was unable to find the least trace of columbic acid, and consequently only the tantalic acid appears in the analysis. If we calculate the atomic equivalents on this basis we obtain the following values:

Ta 35·60, Sn 0·26=35·86 and Fe 11·57, Mn 17·09=28·66

The ratio is then 35·86 : 28·66=$1\frac{1}{4}$: 1 instead of 2 : 1. If we calculate the oxygen ratio on the same basis we obtain 3·1 : 1 instead of 5 : 1; whereas, if we consider that the 79·01 per cent is all columbic acid and calculate the atomic ratios, we obtain for Cb : Fe+Mn, 2·06 : 1 and the oxygen ratio becomes 5·1 : 1; which are very close approximations to the true ratios for columbite. A comparison of Professor Schaeffer's analysis with analyses XII*a* and *b* makes it evident that his specimen was essentially the same mineral.

The assumption that there is no tantalic acid in an Etta columbite is contrary to the results of my tests and analyses, still, it is only on this assumption that the analysis gives a correct ratio showing the mineral to be a columbite, but a very exceptional one for the locality.

In the summer of 1886 or 1887, Mr. Frank Hebert of Grizzly Bear Gulch brought some stream tin to the Dakota School of Mines to have it smelted and the tin run into bars. The yield was exceedingly unsatisfactory and a portion of it was not smelted, but by accident or otherwise was mixed with some stream tin from Bear Gulch, a locality in the Northern Hills. A little over a year ago I examined some of this material and was lead to believe that some of it was tantalite, and the preceding facts not being fully known to me at the time I supposed the tantalite to be from the northern section of the Hills. This was not the case; as I have since found more of it in stream tin from Grizzly Bear Gulch but have found none in the stream tin from Bear Gulch. The stream tin in which I found the tantalite was also from Mr. Hebert's placer ground near the Tin Queen Mine. The largest piece weighs 5 grams and has a specific gravity of 8·2. The mineral has not yet been found in place but these fragments have unquestionably been derived from the Tin Queen lode which lies immediately above the placer ground—this placer is worked for gold. The tantalite is perceptibly harder than the columbite and the streak and powder are dark brown. The method of analysis was the same as for columbite.

I. *Hebert's Placer*, Grizzly Bear Gulch, Pennington Co., S. D. Piece weighed 2·5 grams. II. Same locality, fragment not so large as preceding. III. Same locality, weight of sample 2 grams. IV. *Coosa Co., Ala.*, specimen bought of Messrs. Ward & Howell, Rochester. Weight 3 grams; color black, streak brown. The surface was quite regularly and deeply pitted.

TANTALITE.

	I.	II.	III.	IV.
Sp. Grav.	7·773	7·789	8·200	----
Ta_2O_5	78·20	78·35	82·23	71·37
Cb_2O_5	6·23	6·24	3·57	8·78
SnO_2	0·68	0·58	0·32	5·38
FeO	14·00	14·05	12·67	8·44
MnO	0·81	1·14	1·33	5·37
	99·92	100·36	100·12	99·34
				Ign. 0·20 deducted.
Atom. Equiv.				
Ta_2O_5	35·23	35·29	37·05	32·15
Cb_2O_5	4·65	4·66	2·66	6·55
SnO_2	0·45	0·38	0·21	3·58
	40·33	40·33	39·92	42·28
FeO	19·44	19·48	17·79	11·71
MnO	1·14	1·60	1·59	7·56
	20·58	21·08	19·38	19·27
Atom. Ratio.				
Ta : Cb	8 : 1	8 : 1	14 : 1	5 : 1

I have found several fragments of crystals showing surfaces, and one crystal was sufficiently well preserved to enable me to recognize the habit of the mineral and the following surfaces: 001, strongly etched, two pyramidal surfaces very poorly developed and one prism; the sp. gr. of this crystal is 7·212.

These analyses, especially III, show that these tantalites are poor in columbic acid and manganese. It is remarkable that this should be so, as the columbites of our localities are characterized by a large and often predominating portion of the latter.

I have also found two small specimens of tantalite in the stream tin from Mitchell's Bar, a locality about one and a half miles north by east from the Etta Mine, but no analyses have yet been made of them.

3. MANGANESE COLUMBITE.

The mineral described in this note occurs on the Advance Claim, one of the Dixie group of tin mines, on Elk Creek about one and a half miles south of the Etta mine, Pennington Co., S. D. It occurs in a vein of granite which apparently folds over the crest of the hill; its thickness was not measured

but did not exceed two feet. The columbite was found at only one point: the underside of the granite is here very even and smooth and consists, for about two inches, wholly of mica crystals whose cleavage planes stand at right-angles to the wall. The inner edge of this band of mica is also sharply defined but irregular. The outer surface, that is the under surface as the granite lies, is filled with minute crystals of columbite lying in all directions as though a crop of small crystals had separated first, forming a swarm of them which adhered to the wall and the larger crystals seem to be extensions of these points into the mass; only a few points, however, have developed into larger crystals. If there were two periods of growth, this would account for the peculiar pointed appendages to many of the crystals. Many of these crystals are short, doubly terminated but much distorted, and attached at the side as the more perfect ones indicate.

The band of mica varies in thickness up to two inches and seldom incloses any other mineral than the columbite; the quartz and feldspar, (mono- and triclinic) rest upon the mica while an occasional beryl penetrates its mass. The columbite crystals do not enter the beryl as they do in the Etta mine, but are sometimes found in the feldspar, immediately adjacent to the mica, they are often rusty, and some of them thickly coated with oxide of iron, and the most of them are not at all or only faintly striated.

The crystals have a habit often observed in ordinary columbite, and such approximate angles as can be obtained correspond with those usually accepted. The planes present are: 100, 001, 010, 110, 530, 133, 021. The development of the prisms 530, 110, especially the former, gives the crystals a flattened form in the direction of the macrodiagonal axis.

I. One of the largest crystals, weighing one and a half grams, was used for this analysis; the crystal was rusty, and had to be cleaned by boiling in dilute hydrochloric acid, its color after cleaning was black, luster sub-metallic, a little shining, fracture uneven, streak brown, powder grayish brown. Specific gravity = 6·170. II. Three small crystals, specific gravity not determined. The analyses are as follows:

	I. Sp. grav. = 6·170.	At. equiv.		At. ratio.	II. Sp. grav. undetermined.	At. equiv.		At. ratio.
Cb_2O_5	47·22	35·25	50·90	2·07	45·66	34·07	50·32	2·01
Ta_2O_5	34·27	15·44			35·53	16·00		
SnO_2	·32	·21			·38	·25		
FeO	1·89	2·62	24·59	1·	2·29	3·04	25·01	1·
MnO	16·25	21·97			16·25	21·47		
	99·98				100·00			

Ratio Cb : Ta = 7 : 3, Fe : Mn = 2 : 17.

The results of I and II agree as closely as could be expected when we consider that each of the three different crystals of II may have, and probably did, represent different molecular mixtures.

ART. XII.—*Notes on the Geology of the Florida Phosphate Deposits;* by N. H. DARTON.

DURING the past year the phosphate deposits of Florida have become of considerable commercial importance and attracted widespread interest. As practically nothing was on record as to their geologic relations the writer has devoted several weeks to a preliminary study of the principal deposits and this paper is a summary of the results.

The phosphate regions of Florida occur mainly in the western and west-central portions of the peninsula, comprising a series of irregular areas scattered at varying intervals along a narrow belt extending from near Tallahassee towards Gainesville and thence nearly to Charlotte Harbor, a distance of 250 miles. The entire region is not yet fully explored but the vast extent and commercial importance of the deposits are satisfactorily established and it is safe to predict that Florida will finally become a prominent source of phosphate. The deposits are exceedingly irregular in extent and richness, and while there are many areas underlain by large bodies of high grade mineral, the great number of the deposits consist of impure, thin or scattered beds of no economic value.

The phosphates are readily separable into three classes: 1. *Rock phosphate*, a homogeneous, more or less completely lithified, light colored phosphate of lime, constituting the surface of the middle Tertiary limestone formation. 2. *Conglomerate*, consisting of pebbles of phosphate rock imbedded more or less thickly in a matrix of phosphate sand, marl and arenaceous and argillaceous materials. This fragmental formation lies in great sheets on the surface of the limestone, in some cases overlapping the edge of the rock phosphates, from which its pebbles were derived. 3. *River drift*, consisting of phosphate pebbles derived both from the *rock phosphate* and the *conglomerate* and constituting great placer deposits in the stream beds draining the other phosphate regions.

So far as is known the occurrence of the *rock phosphate* is restricted to a narrow irregular belt extending through eastern Citrus county, northward through western Marion, probably to the exposures near Albion, and thence with more or less continuity through Trenton in Alachua, Steinhatchee in Lafayette

and Lauraville in Sewanee, possibly to Monticello, in Jefferson, Perry in Taylor, and some other reported localities in the same direction. This region is not by any means underlain by a continuous sheet of phosphate but includes irregular masses of variable sizes and thickness scattered about in detached bodies often widely separated by barren limestone areas.

At Dunellon in western Marion county there are representative exposures in the extensive mine openings that are now being worked. Here the phosphate was found outcropping at a number of points in the woods and in low bluffs and reefs in the Withlacoochee river near by. The deposit appears to constitute a large basin of which the bottom was not reached in a thirty-foot pit in the center. The phosphate is in large part a mixture of chalky and flinty rock similar in texture and structure to spongy limonite, but usually creamy white, gray or bluish gray in color. Some portions consist of dense homogeneous lithified materials, others are spongy, stalactitic or laminated. A fair average sample of high grade mineral was found to contain 83 per cent of phosphate of lime and $4\frac{1}{2}$ per cent of carbonate of lime.

The *Conglomerate* phosphates occupy a very considerable area in Florida, and although not as rich in phosphate of lime as the phosphate rock they will be of commercial importance. The principal deposits now known are south of the southern termination of the rock phosphate belt, in the western part of Polk county in the vicinities of Bartow and Fort Meade, where they constitute sheets of wide area overlying the limestone, sometimes to a thickness of from twenty to thirty feet. These conglomerate phosphates consist of small pebbles of 80 to 85 per cent phosphate rock, usually light colored, imbedded in a soft chalky matrix of phosphate sand, carbonate of lime, clay and sand in variable proportions. High grade conglomerate will average from 73 to 78 per cent of phosphate of lime.

At intervals along the eastern border of the rock phosphate region and overlapping it at some points there are fragmental and conglomerate deposits of considerable extent but they are much more diverse in composition than the great sheets in Polk county. At the Dunellon mine, northern opening, there is a deposit of this class and the porous, pebbly sandrock—"Chimney rock" of the Gainesville region appears to belong to the same formation.

The *River drift* deposits of phosphates are of great economic importance, for they are rich in phosphate and can be mined at small expense. Nearly every little water course in the phosphate regions contains accumulations of phosphate

pebbles and along the larger streams there are many thick and extensive pebble deposits. Peace Creek drains the Bartow-Fort Meade conglomerate region and flows over many great placer deposits, some of which are now extensively worked in De Soto county. The Withlacoochee, near Dunellon, and Alifia Creek northeast of Bartow also contain extensive accumulations of pebbles. These deposits consist of rock-phosphate pebbles usually from an inch to one-quarter inch in diameter, mixed with more or less sand and usually with bone fragments and occasional flint pebbles from the limestones.

Age and geologic history.—The three geologic formations to which the phosphates belong are distinctly separate stratigraphically, and represent a long interval of geologic time. The rock phosphates appear to be the deeply eroded remnants of the phosphatized surface of the middle Tertiary limestone; the conglomerate deposits overlie these limestones unconformably and in the Gainesville region at least, appear to be Miocene in age, and the river drift deposits are apparently entirely subsequent to the great mantle of Pleistocene white and gray sands which covers the entire peninsula to a greater or less depth.

Excepting in its light color the rock phosphate is a physical counterpart of the brown limonite iron ores of the Appalachian limestone valleys and the deposits have very similar structural relations. I have found at a number of localities that the massive phosphate graduates into the limestone usually by short transitions and many areas were discovered in the phosphate belt and under the conglomerate in the Bartow region where the limestone is only partially phosphatized. In the mines at Dunellon the massive phosphate is apparently continuous with the limestones, but unfortunately at the time of my visit there were no continuous exposures from rich phosphate to the walls of the basin, and the bottom was not yet reached, so I was unable to establish a graduating sequence at that locality. There are, however, in the massive phosphate, occasional casts and impressions of the same middle Tertiary mollusca undoubtedly lying as they were originally deposited.

The origin of the phosphate of lime is not definitely known, but it seems exceedingly probable that guano was the original source and the genesis of the deposits similar to that of the phosphates on some of the West Indies. Two processes of deposition have taken place, one the more or less complete replacement of the carbonate of lime by phosphate of lime, and the other a general stalactitic coating on the massive phosphates, its cavities, etc.

The apparent restriction of the rock-phosphate deposits to the western "ridge" of Florida may have some special bearing on their genesis but at present no definite relationship is perceived. The aggregate amount of phosphate rock distributed in fragmentary condition in the various subsequent formations is very great, greater by far than the amount remaining in its original position and it is possible that the area at one time included the greater part, if not all, of the higher portions of the peninsula. As this region apparently constituted a long, narrow peninsula or archipelago, during early Miocene times, it is a reasonable tentative hypothesis that during this period guanos were deposited from which were derived the material for the phosphatization of the limestone, either at the same time or soon after.

The pebbles of the conglomerate phosphate were undoubtedly derived from the rock phosphates, for they are identical in appearance and composition and overlap them as a shore deposit. Evidence in regard to the age of the conglomerate formation is very meager. The only organic remains I met with were two imperfect casts of Pectens in the "Chimney rock" near Gainesville. These had a Miocene aspect but the evidence is not by any means conclusive. This "Chimney rock" of Gainesville is a porous sandstone containing a small proportion of pebbles of phosphate rock, lying unconformably above the Vicksburg limestone. It is the structural equivalent of the conglomerate beds of the Polk county region but they may prove not to be identical in age.

The phosphate deposits of Florida will require careful detailed geologic exploration before their relations and history will be fully understood, and it is the purpose of these preliminary notes only to throw some light on their more general features.

ART. XIII.—*Record of a deep Well at Lake Worth, southern Florida*; by N. H. DARTON.

IN June, 1890, a well was completed at Lake Worth, on the southeastern coast of Florida, which penetrated the great sand mantle and extended down into the Vicksburg limestone to a depth of 1212 feet. It was bored by Mr. J. A. Durst, who has very kindly placed the borings at my disposal.

Unfortunately, no samples were collected for the first 400 feet, and there are several other gaps for which information is lacking. Notwithstanding its imperfections the section is an

exceedingly important one, for it throws some light on the general stratigraphy of a portion of Florida of which little was hitherto known. The well record is as follows:

0– 400 feet.	"Sands with thin layers of semi-vitrified sand at 50 and 60 feet."
400– 800 feet.	Very fine grained soft, greenish gray quartz sand, containing occasional foraminifera and water-worn shell fragments.
800– 850 feet.	No sample.
850– 860 feet.	White sands with abundant foraminifera of four or five species.
860– 904 feet.	No sample.
904– 915 feet.	Gray sands containing sharks' teeth, small water-worn shell and bone fragments, sea urchin spines and lithified sand fragments.
915–1000 feet.	No sample.
1000–1212 feet.	Samples at frequent intervals. Vicksburg limestone containing Orbitoides in abundance throughout, together with occasional indeterminable fragments of molluscan casts, corals and echinoderms. It is a creamy white, hard homogeneous limestone throughout.

There was also sent a box containing two species of Dentalium and a Turritella, all of Miocene facies, but, unfortunately, no data could be furnished in regard to the depth at which they were found.

The ages of the series overlying the limestones could not be determined definitely from the material received, but the organic remains from 800–915 feet suggest Miocene, especially if the unlabeled sample belongs here, which is probable. The 400–800 feet beds contain several of the same foraminifera that are found at 850–860 feet, and probably are part of the same formation.

ART. XIV.—*On the Chemical Composition of Aurichalcite;* by S. L. PENFIELD.

THE material for the analysis in this paper was received by Professor E. S. Dana some years ago from an unknown locality in Utah. Very good specimens of aurichalcite occur at both the Kesler Mine, Big Cottonwood and Cave Mine, Beaver Co., Utah, and the specimen under investigation very closely resembles one from the Kesler Mine in the cabinet of Professor Geo. J. Brush. As some question still exists regarding the

formula of aurichalcite and as the mineral appeared to be of unusual purity the following investigation was undertaken to determine if possible its true chemical composition.

As far as can be told from the small hand specimens in the author's possession, the mineral occurs in narrow seams about one centimeter wide in an impure limonite; calcite was associated with it, especially on one side of the seam and great care was taken to pick out pure material. The aurichalcite had the usual pale bluish-green color and occurred in radiated tufts of microscopic crystals so soft and loosely aggregated that a cluster of them could readily be pressed to a powder between the fingers. No definite idea regarding its crystallization was obtained by examining under the microscope. It was seen that it occurred in little flattened prismatic crystals with mostly broken, irregular contours in general agreeing with the description given by A. Belar.*

After ascertaining that the mineral did not lose water by heating at 100° C. the larger selected fragments were boiled in water to expel the air from between the crystals and the specific gravity taken very carefully on a chemical balance; the two portions were then analyzed separately with the following results.

	No. I.		No. II.	
Weight of mineral	0·5690		0·3342	
Specific gravity	3·52		3·63	
CO_2	16·50		16·22	
CuO	20·88		19·87	
ZnO	52·18		54·01	
H_2O	9·91	$CaCO_3$	9·93	$CaCO_3$
CaO	·86	= 1·53	·36	= 0·64
	100·33		100·39	

The finely powdered mineral, weighed in a platinum boat, was ignited in a combustion tube and the CO_2 and H_2O collected and weighed in the ordinary absorption apparatus. The copper was separated from the zinc by two precipitations from strong hydrochloric acid solutions with hydrogen sulphide. The larger percentage of CuO in the first analysis is not owing to an incomplete separation of copper from the zinc, as proved by dissolving the copper, after having weighed it, precipitating it a third time and finding no trace of zinc in the filtrate. The variation of CuO and ZnO in the two analyses indicates the mutual replacement and isomorphism of the two oxides. The CaO comes undoubtedly from an admixture of calcite. Correcting the specific gravity and the percentages for 1·53

* Zeitschr. Kryst., xvii, p. 113.

and 0·64 per cent. of calcite respectively in the two analyses, we have the following with the molecular ratios.

	I.			Ratio.	II.			Ratio.	Theory for $2RCO_3$, $3R(OH)_2$ where Cu : Zn = 2 : 5
Sp. Gr.,	3·54				3·64				
CO_2	16·07	·365		1·98	16·04	·365		1·98	16·14
CuO	21·21	·267	·919	5·00	20·00	·252	·921	5·00	20·79
ZnO	52·99	·652			54·36	·669			53·17
H_2O	10·06	·559		3·04	9·99	·555		3·02	9·90
	100·33				100·39				100·00

The ratios in the two analyses are almost exactly 2 : 5 : 3 and the formula is therefore $2RCO_3$, $3R(OH)_2$ in which R = Zn and Cu. There seems to be no exact relation between the CuO and the other constituents. In analysis I the CuO : ZnO = about 2 : 5 and using this proportion in the above formula the theoretical composition given above was calculated, which agrees very well with the first analysis.

The strongest proof of the correctness of the above formula is found in the purity of the analyzed mineral and the exactness of the ratio between CO_2, RO and H_2O, both of these are as satisfactory as one could desire in mineral analysis, especially for a mineral occurring in minute tufted crystals in a narrow seam with calcite. Moreover the above formula is the same as that proposed by T. Böttger* in the original description of aurichalcite from Loktewsk in the Altai. His analysis was made in Rose's laboratory with great care and evidently on very pure material.

Other analyses have shown a deviation from the above formula which may have resulted from impurities in the analyzed material or errors of analysis. Thus Delesse† has described as buratite specimens from Loktewsk in the Altai and from Chessy, France, containing as high as 8·62 per cent of CaO, but as A. Belar‡ and others have proved that CaO is not a normal constituent of aurichalcite, it is quite safe to assume that the material which he analyzed contained calcite; in fact if $CaCO_3$ equivalent to the CaO be deducted from his analyses the remainder corresponds closely to the above formula. Other analyses cannot be used in discussing the formula because CO_2 and H_2O have not been separately determined; they are given together simply as loss on ignition.

A. Belar in a recent contribution on this subject, already noticed, gives four analyses of material carefully selected under the microscope so as to avoid all possible impurities. The analyses are as follows:

* Pogg. Ann., xlviii, p. 495, 1839.
† Ann. Ch. Phys., xviii, 478, 1846.
‡ Loc. cit.

I. Moravicza in Banat.
II. " "
III. Campiglia, Italy.
IV. Sardinia.
V. Theory according to Belar for $CuCO_3$, $3Zn(OH)_2$.
VI. Theory according to the original formula $2RCO_3$, $3R(OH)_2$, $Cu : Zn = 2 : 5$.

	I.	II.	III.	IV.	V.	VI.
Loss on ignition	24·91	26·78	26·50	22·97	23·30	26·04
H_2O	13·53				12·84	9·90
CO_2	[11·38]				10·46	16·14
CuO	20·39	21·43	20·20	15·58	18·91	20·79
ZnO	54·70	53·57	55·51	58·72	57·79	53·17
	100·00	101·78	102·21	97·27	100·00	100·00

Water was determined directly only in the first of these analyses, and CO_2 by deducting H_2O from the loss on ignition, or indirectly by deducting the sum of all the other constituents from 100 per cent. From this analysis Belar derives the formula $CuCO_3$, $3Zn(OH)_2$ requiring a ratio of $CO_2 : RO : H_2O = 1 : 4 : 3$ while his analysis yields $1·11 : 4·00 : 3·24$, an agreement which is not satisfactory as may also be seen by comparing the theoretical composition V with analysis I. The other analyses are of little value as they do not add up very close to 100 per cent and in II and III the loss on ignition is certainly nearer to the theory for the original formula, VI above, than for Belar's V. It is possible that Belar's analysis I is correct and that there is a mineral resembling aurichalcite with a definite formula, but if so it must be settled by more exact analyses and be designated as a distinct species.

An analysis by Berzelius* of an artificial salt, prepared by precipitation from a solution of zinc sulphate with sodium carbonate in the cold, washing the precipitate and drying to constant weight in a vacuum, is of interest here as he derived for it a formula exactly analogous to that of aurichalcite, $2ZnCO_3$ $3Zn(OH)_2$. His analysis, together with the theoretical composition are given below.

	CO_2	H_2O	ZnO
Berzelius, found	15·939	10·714	73·347 = 100·000
Calculated	16·06	9·85	74·09 = 100·00

In closing the author desires to express his thanks to Prof. E. S. Dana for his kindness in furnishing the material for carrying on this investigation.

Mineralogical Laboratory, Sheffield Scientific School,
New Haven, Nov. 22d, 1890.

* Berzelius, Jahresbericht, xv, p. 180, 1836.

ART. XV.—*The Compressibility of Hot Water and its Solvent Action on Glass*;[1] by CARL BARUS.

1. BETWEEN 0° and about 63°, the compressibility of water continually decreases. After this, if temperature rises further, the compressibility increases. It was my original purpose to supplement these results by determining the compressibility of water between 100° and 300°; but I did not get further than 185°, for the reason that at this temperature (and obviously much below it) liquid water attacks glass so rapidly as to make the measurements in glass tubes worthless.

2. The peculiar behavior, in question, has interested many physicists. Grassi[2] was the first to find that the compressibility (β) of water decreases with temperature, being $50/10^6$ at 0° and $44/10^6$ at 53°. He also observed that the compressibility of solutions is less than that of water. Amaury and Descamps[3] substantiate the latter result; but they only observe at a single temperature 15°, at which $\beta=45/140^6$. In Cailletet's[4] experiments carried as far as 700 atm., only a single temperature is given, and the same is true of Buchanan's[5] results. After this the subject was vigorously attacked by Tait[6] and his pupils, at first particularly with reference to the depression of the temperature of maximum density of water, under pressure. The probability of such an occurrence had been inferred by Puschl and by van der Waals[7]. Cf. Grimaldi, l. c. In later experiments Tait[8] studies the thermal relations of the compressibility of water, but only for small ranges of temperature. Further results are due to Pagliani and Palazzo[9] working with mixtures of water and alcohol, but more directly to Pagliani and Vicentini.[10] These observers corroborate Grassi's work, and find that water shows minimum compressibility at 63°. Grimaldi[11] critically reviews the maximum density experiments of Puschl, of van derWaals, of Marshall Smith and Omond, and of Tait.

[1] This paper will be recognized as part of the work suggested by Mr. Clarence King.

[2] Grassi: Ann. de ch. et de phys., (3), xxxi, p. 437, 1851; cf. Wertheim: ibid. (3) xxiii, p. 434, 1848.

[3] Amaury and Descamps: C. R., lxviii, p. 1564, 1869.

[4] Cailletet: C. R., lxxv, p. 77, 1872.

[5] Buchanan: Nature, xvii, p. 439, 1878.

[6] Tait: Proc. Roy. Soc. Ed., xi, p. 204, 1881; Marshall, Smith and Omond: ibid., xi, pp. 626. 809, 1882; Tait: ibid., p. 813; ibid., xii, 1882–83, p. 226; ibid., xiii, p. 2, 1884-85.

[7] Vander Waals: Beiblätter, I, p. 511, 1877.

[8] Tait: Proc. Roy. Soc. Ed, xii, p. 45, 1882–83; ibid., p. 223; ibid., 1883–84 p. 757.

[9] Pagliani and Palazzo: Beiblätter, viii, p. 795, 1884.

[10] Pagliani and Vicentini: Beiblätter, viii, pp. 270, 794, 1884; Journ. de phys., (2) xxx, p. 461, 1883.

[11] Grimaldi: Beiblätter, x, p. 338, 1886.

Amagat* applying a new method of pressure measurement "a piston libres," operates with hydrostatic pressures as remarkably high as 3000 atm., and at temperatures between 0° and 50°. He shows among other results relating as yet chiefly to thermal expansion, that the compressional peculiarities of the behavior of water vanish at high pressures and increasing temperatures (interval 0° to 50°), thus further corroborating Grassi. Many data are given; but the research is unfinished. Tait† in a final paper summarizes much of his work and begins a series of experiments showing that the effect of solution is analogous to an increase of internal pressure. A critical revision of earlier work on compressibility may be found in Tait's "Properties of Matter."

From this brief summary it appears that results anticipating the contents of the present paper are not in hand. There is another class of experiments relating to the expansion of water in glass tubes to which I must advert. Waterston‡ published a very full series of results carrying the work as far as 300°. He was annoyed by the action of water on glass, but does not further consider it. For very high temperatures the experiments of Daubrée§ and others, are well known.

3. In the present work pressures were applied by aid of Cailletet's large force pump. The thread of water is enclosed in a capillary tube, between two end threads of mercury, and the distance apart of the two inner menisci, corresponding to any given temperature and pressure, measured by Grunow's cathetometer. The tube, suitably closed above, is exposed in a vapor bath (boiling tube). At 185° (aniline), the thread of water soon loses its transparency, becoming white and cloudy. Fortunately the siliceous water is translucent. By placing a very bright screen behind it, the demarcation between water and mercury remains sufficiently sharp for measurement. After the action has continued for some time, say an hour, the columm is solid at high pressures (300 atm.), though it is probably only partially so at 20 atm. In consequence of this, threads of mercury break off during advance and retrogression of the column. Further measurement is therefore not feasible. Toward the close of the experiment, moreover, the mercury thread is pushed forward, enclosed by walls of semi-solid siliceous water. The thread is therefore of smaller diameter and the measurement correspondingly inaccurate.

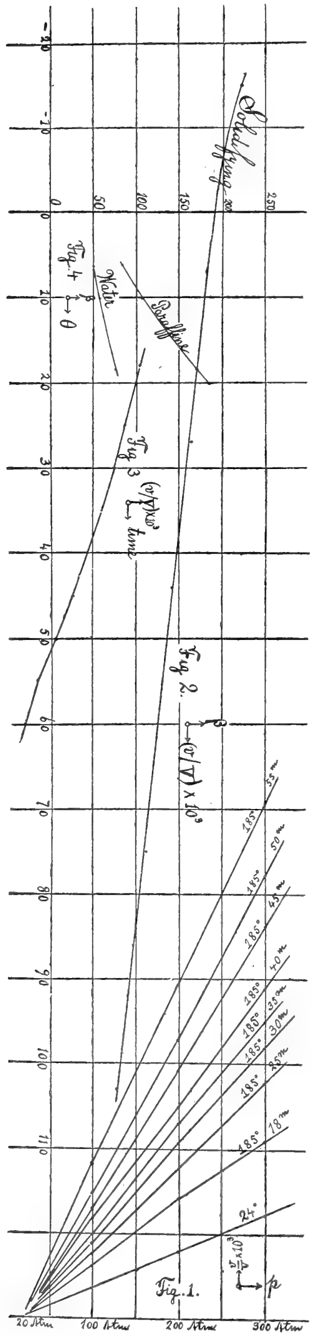
In obtaining these data, I followed a customary routine of increasing pressure from zero to the maximum, then decreasing

* Amagat: C. R., ciii, p. 429, 1886; ibid., civ, p. 1159, 1887; ibid., cv, p. 1120, 1887.

† Tait: Challenger Reports, ii, part 4, 1888.

‡ Waterston: Phil. Mag., (4) xxvi, p. 116, 1863.

§ Daubrée: Et. synthét. d. Géol. expér., 1879, p. 154 et seq., Paris, Dunod.



An explanation of this chart is given in § 8.

it from the maximum to zero, and taking the mean volume changes corresponding to a given pressure. When the water does not attack the glass, the fiducial mark (pressure low) at the beginning of the series, is regained at the end. When water attacks glass there is much shifting. The glass was common lead glass and distilled water was used.

4. My introductory work between 0° and 100° contains a mere corroboration of some of the results given in § 2. As it is not exceptionally accurate I will omit it here.

5. In table 1, the symbols used have the following meaning: L is the observed length of the thread of water, θ its temperature, and t the mean time of observation. v/V is the volume decrement due to the pressure p. Finally β is the mean compressibility;* i. e. $\beta=(1/p)(v/V)$. The first series of data were obtained at 28°, the next seven series at 185°. Unfortunately I did not observe the time when ebullition commenced, and some subsequent dates are also lacking. After closing the experiments, I noticed that a fine filament of the upper thread of mercury, had run down into the core of the solid silicate below it. Possibly this means that there had been progressive erosion due to water intruding between the mercury and the glass. In this respect the observations are uncertain. § 7.

6. To discuss these results I first plotted v/V as a function of p, thus obtaining a series of curves of somewhat irregular contour, the character of which, however, is obvious. This will be more accurately observed by plotting β as a function of the length L of the column, since the time data are incomplete. The result is striking. It shows a mean

* It would be useless to calculate β by more elaborate means. The correction referred to at the end of this paragraph is such, that if applied, it would accentuate the inferences of the text. Its small value appears in § 7.

TABLE 1.—COMPRESSIBILITY OF WATER.

L, θ, t	p.	$\frac{v}{V}\times 10^3$.	$\beta\times 10^6$.	L, θ, t	p.	$\frac{v}{V}\times 10^3$.	$\beta\times 10^6$.
	Atm.				*Atm.*		
28°	20	0·0	----	185°	20	0·0	----
18·44^{cm}	100	3·5	44	19·57^{cm}	100	9·3	116
	200	9·4	52		200	20·6	114
	300	13·4	48		300	32·7	117
	400	18·5	49		400	42·8	113
185°	20	0·0	----	185°	20	0·0	----
20·45^{cm}	100	6·7	84	18·92^{cm}	100	11·7	146
	200	14·4	80	11^{h}·05^{m}	200	25·9	144
	300	21·1	75		300	39·7	142
	400	29·3	77		400	55·5	146
185°	20	0·0	----	185°	20	0·0	----
20·10^{cm}	100	8·8	100	18·42^{cm}	100	----	----
	200	17·1	95	10^{h}·10^{m}	200	30·1	167
	300	27·4	98		300	44·6	159
	400	34·7	91		400	60·2	158
185°	20	0·0	----	185°	20	0·0	----
19·94^{cm}	100	8·1	101	17·78^{cm}	100	15·0	188
	200	18·3	102	11^{h}·20^{m}	200	31·7	176
	300	27·9	100		300	56·2	201
	400	38·3	101		400	71·8	189

increment of β, of about $50/10^6$ per centimeter of decrement of length of column. Toward the end of the experiment, the values of β increase much faster; but here they are uncertain because of solidification. The total observed decrement of L is therefore $(20·1-17·8)/20·1$, or more than 11 per cent. Since the column at the moment when ebullition started must have been longer, it follows that the volume of the *system* of pure water and solid glass, shrinks more than 11 per cent, in virtue of the solution of glass in water, up to the point of solidification at 185°. By plotting length L as a function of time, the data though incomplete show that volume contraction of the kind given took place at the rate of 3 per cent per minute. The column therefore at 185° is soon shorter than the original column at 28°. This is an enormously rapid rate; for were it possible for such action to be indefinitely prolonged, the column would be quite swallowed up in five hours. Hence it appears improbable that the action of water on glass will be unaccompanied by heat phenomena. Of course the rate of solution must increase, as the diameter of the capillary tube decreases.

7. From the importance of these results I resolved to repeat them with greater precautions. Table 3 contains the data given on the plan of table 1. The first series holds for 24°; the remaining nine series for 185°. Time is given in minutes from the period when ebullition of aniline had fairly set in;

though this cannot be sharply determined. The experiment lasted about one hour. A subsidiary table 3, contains the essential results (time, temperature θ, volume decrement v/V, compressibility β) of table 2. The experiment was satisfactory throughout.

TABLE 2.—COMPRESSIBILITY OF WATER.

θ, L, t	p.	$\frac{v}{V}\times 10^3$.	$\beta\times 10^6$.	θ, L, t	p.	$\frac{v}{V}\times 10^3$.	$\beta\times 10^6$.
	Atm.				*Atm.*		
24°	20	0·0	----	185°	20	0·0	----
13·96^{cm}	100	3·6	45	14·80^{cm}	100	9·8	123
	200	7·9	44	35^{m}	200	22·9	127
	300	12·2	44		300	35·0	125
*185°	20	0·0	----	185°	20	0·0	----
15·42^{cm}	100	6·2	77	14·58^{cm}	100	11·7	146
18^{m}	200	14·2	79	40^{m}	200	24·9	138
	300	21·0	75		300	38·9	139
185°	20	0·0	----	185°	20	0·0	----
15·17^{cm}	100	7·6	95	14·34^{cm}	100	12·9	161
25^{m}	200	17·7	98	45^{m}	200	29·3	163
	300	27·8	99		300	46·1	165
185°	20	0·0	----	185°	20	0·0	
15·01^{cm}	100	8·7	109	14·03^{cm}	100	14·7	184
30^{m}	200	20·6	114	50^{m}	200	32·8	182
	300	31·9	114		300	52·0	186
				185°	20	0·0	----
* Commenced boiling at 0^{m}.				13·75^{cm}	100	18·3	229
				55^{m}	200	39·4	219
					300	60·5	216
				185°	Threads broken off.		
				13·56^{cm}	Measurement uncertain.		
				60^{m}	Siliceous water, solid.		

TABLE 3.—*Expansion and Compressibility of Silicated water, referred to water at 24° and 20 atm.*

θ.	$\frac{v}{V}\times 10^3$.	$\beta\times 10^6$.	Time.	θ.	$\frac{v}{V}\times 10^3$.	$\beta\times 10^6$.	Time.
24°	± 0	44	----	185°	+ 44	141	40^{m}
185°	+103	77	18^{m}	185°	+ 27	163	45^{m}
185°	+ 86	97	25^{m}	185°	+ 05	184	50^{m}
185°	+ 75	112	30^{m}	185°	− 15	221	55^{m}
185°	+ 60	125	35^{m}	185°	− 29	----	60^{m}

8. The discussion of this table can be given on the lines followed in case of § 6. Note at the outset that after 55^{m} have elapsed since exposure to 185°, the hot turbid column is not so long as the original cold clear column at 24°. The hot compressibility after 55^{m} has increased to five times the cold compressibility, and to three times the original hot compressibility.

Some allowance must however be made for the attenuated thread of mercury (§ 3). If v/V be plotted as a function of p, a series of curves is obtained as shown in figure 1. Considering the difficulties of measurement, they are satisfactorily regular. Temperature and time are affixed to each curve. In table 3, (v/V) is rigorously the ratio of increment of length to the original length at 24°, due to thermal expansion and concomitant chemical action. The radius of the tubes widens as solution proceeds; but the datum (v/V) suffices for the present purposes. Let β be represented in its dependence on (v/V). The plotted curve is a line of remarkable regularity, as shown in figure 2. It follows from the chart that β increases $11/10^6$ for each per cent of volume decrease of the water undergoing silicification. This is about $75/10^6$ per centimeter of length, agreeing substantially with the former result. Again v/V decreases 13 per cent for the interval of observation of 42^m, or about ·3 per cent per minute, thus again agreeing with § 6. See figure 3.

Suppose the line for β and (v/V) to be prolonged as far as $(v/V) = 130/10^3$, which holds for time $= 0$. The datum for β so obtained, ought to give me the normal compressibility of pure water at 185°. Making the prolongation, however, I find an excessively small result $\beta = 50/10^6$ nearly. This merely shows, since chemical action is very rapid, that the time at which it commenced is only roughly indicated. It is probable nevertheless that β_{185} will not be greater than $70/10^6$. Hence even above 100° the compressibility of water increases at a very low rate with temperature; at a rate about $\frac{1}{4}$ that of paraffine, for instance. Cf. figure 4. I think this indicates exceptional stability of the water molecule.

9. Now what is the underlying cause of the action described? Clearly I think, an instability of the glass molecule at 185°, much rather than any instability of the water molecule. This is an accordance with the evidence I adduced in studying the electrolytic conduction of stressed glass,* and corresponds also to the diminished viscosity of glass† at the stated temperatures. At 185° the cohesive affinities‡ of the water are sufficient to disintegrate the glass molecule.

The increase of β with time must be due to the solution of silicate. Indeed it would be difficult to devise an experiment, in which the progress of the continued solution can be so well discerned as is possible in the present incidental results. I am

* Barus: This Journal, xxxvii, p. 339, 1889.

† Barus and Strouhal: This Journal, xxxi, p. 439, 1886; ibid., xxxii, p. 181, 1886.

‡ A term which will be defined succinctly in the course of the present series of papers.

aware that the march of β is to be interpreted with reference to Wilhelmy's* time law of reaction; but the discussion is somewhat involved and must be omitted.

Curiously enough the effect of solution is here an *increase* compressibility, whereas in all other cases (§ 2), it is a decrement of compressibility. I leave this without comment, believing however, that the silicate during the course of the oscillations of pressure, passes through states of unstable equilibrium with its water. The apparent compressibilities measured, are really solution phenomena, since the silicate present passes from a lower to a higher state of hydration when pressure passes from the lower to the higher value. For this reason compressibility increases with the quantity of silicate present, in other words with the time during which the solvent action has been going on. Something of this kind I formerly observed in case of moist mono-chloracetic acid. The possible occurrence of lag, though I did not search for it, would be obscured by the contraction of the silicated column of water. If a reaction is superinduced in a system of solid and liquid by presssure, the curious question is thus presented whether the reaction is more complete in proportion as the acting pressure is higher; or more generally whether the final progress of the reaction, or the chemical equilibrium varies with pressure. To my knowledge in all the relevant instances examined (take the action of acid on zinc under pressure of the gas evolved) this is true.

As a general deduction from the above experiments I infer, that in many instances a definite dissociation temperature of the solid must first be surpassed, before solution will set in. Elsewhere I shall show that the recognition of this principle, regarded at the outset as a mere working hypothesis, has enabled me to effect the complete solution of a valuable class of commercial products.

* Wilhelmy: Pogg. Ann., lxxxi, pp. 413, 499, 1850.

ART. XVI.—*An Attempt to harmonize some apparently conflicting Views of Lake Superior Stratigraphy;** by C. R. VAN HISE.

[Read at the Wisconsin Academy of Science, Arts and Letters, Madison, Dec. 30, 1890.]

IN attempting to determine how far the different views held as to Lake Superior stratigraphy are really in harmony, we have as starting planes an upper and a lower horizon. The first of these is the base of the Keweenaw Series. All are agreed that below this series is an unconformity more or less considerable. The lower of these planes lies between the crystalline schist-granite gneiss complex and the overlying clastics. Below this plane is found Irving's Fundamental Complex, Lawson's Coutchiching and Laurentian, the Profs. Alexander and N. H. Winchells' Vermilion Lake and Laurentian. Whether this plane is definitely fixed by a great unconformity will not here be discussed, as the wish is rather to dwell upon points of agreement than those of difference. That it is so fixed is maintained by Irving† in a series of papers. Lawson‡ agrees with Irving that this plane is marked by a great change of conditions of deposition and a probable unconformity in Ontario. Prof. Pumpelly, who has recently made a rather extended trip in western Ontario, acquiesces in this conclusion. Of the extension of these same series in Minnesota, the Profs. Winchell,§ although recognizing this plane as the boundary between two groups of rocks, maintain conformity. Bell‖ now stands almost alone in the contention that this lower plane cannot be recognized. In the older work of the Canadian Survey all of the groups of rocks included between the above planes have been placed as Huronian, and

* This paper is in large measure the same as the part on correlation in a memoir upon the Penokee Series of Michigan and Wisconsin to be published as a monograph of the U. S. Geol. Survey.

For the distribution of the rock-series discussed in this paper, see Irving's Preliminary Geological Map of the Lake Superior Region, 5th Ann. Rept. U. S. Geol. Survey, p. 181.

† Copper-Bearing Rocks of Lake Superior, U. S. Geol. Survey, Monograph V; Divisibility of the Archaean in the Northwest, this Journal, III, xxix, pp. 237–249, 1885; On the Classification of the Early Cambrian and Pre-Cambrian Formations, U. S. Geol. Survey, Seventh Ann. Rept.; Is there a Huronian Group? This Journal, III, xxxiv, 204–249; Explanatory and Historical Note by R. D. Irving to Bulletin U. S. Geol. Survey No. 62, The Greenstone Schist Areas of the Menominee and Marquette Regions of Michigan, by George H. Williams.

‡ Report on the Geology of the Rainy Lake Region, Andrew C. Lawson: Geol. and Nat. Hist. Survey of Canada, Annual Report 1887, part F, p. 141.

§ Geol. and Nat. Hist. Survey of Minn., 16th Ann. Rept., 1887, pp. 365–366. Ibid., 17th Ann. Rept., 1888, pp. 66–67.

‖ The Huronian System in Canada. Robert Bell: Trans. Royal Soc. Can., 1888, vol. vi, sec. 4.

also a part of the rocks included in Irving's Fundamental Complex, Lawson's Coutchiching, and Prof. Winchells' Vermilion Lake series. Irving* has shown conclusively that certain of the rocks on the south shore of Lake Superior, first loosely placed with the Huronian are to be excluded from it. This work has been so thoroughly supplemented in the United States by the Profs. Winchell, and in Canada by Lawson that at the present time this conclusion can hardly be questioned.

It is believed that many of the difficulties as to correlation in the districts about Lake Superior have largely arisen from the failure to generally recognize a physical break, which has a very wide if not universal extent in the Lake Superior region. So far as I know, the first descriptions of this break are by Foster, and Foster and Whitney† in the Marquette district. It was next noted by Brooks.‡ By Rominger§ it was seen at many points which lead to the suggestion "That great disturbances of not only a local extent, must have occurred at the end of this era of iron sediments." Wadsworth‖ says of it, these conglomerates "Mark old beaches water-worn after the jasper and ore were *in situ*, in nearly their present condition, and, if the logic of the geologists of the Michigan and Wisconsin surveys were carried out, these unconformable detrital formations would mark a new geological age."

Foster C. Whitney and Dr. Wadsworth, however, maintaining the eruptive origin of the jasper and ore, do not believe that the conglomerates thus mark a new geological age. The real significance of the break was recognized by Prof. Irving,¶ who not only found it in the Marquette district, but knew of its equivalent in the Vermilion Lake district of Minnesota. The break in the Marquette district was lately noted by Prof.

* In papers above cited.

† Report on the Mineral Lands of Lake Superior, J. W. Foster: Ex. Docs., 1848–49, 2d Sess., 30th Cong., vol. ii, No. 2, p. 161. Geology of the Lake Superior Land District, J. W. Foster and J. D. Whitney: Senate Docs., 1851, Spec. Sess., 32d Cong., vol. iii, No. 4, pp. 23, 43 and 67.

‡ Iron-Bearing Rocks of the Upper Peninsula of Michigan, T. B. Brooks; Mich. Geol. Survey, 1873, vol. ii, pp. 128–129, 133.

§ Upper Peninsula of Michigan, C. Rominger, Mich. Geol. Survey, 1881, vol. iv, pp. 74–75.

‖ Notes on the Geology of the Iron and Copper Districts of Lake Superior, M. E. Wadsworth: Bull. Mus. Comp. Zool., 1880, vol. vii, pp. 30–31.

¶ Preliminary Paper on an Investigation of the Archaean Formations of the Northwestern States, R. D. Irving: Fifth Ann. Rept. U. S. Geol. Survey, 1885, p. 193. "I refer to the occurrence in the quartzites overlying the ores, at several of the Marquette mines, of abundantly rounded fragments derived from the ore below. A very much more striking occurrence of this kind is met with in the Vermilion Lake district of Minnesota, where the fragments included in the conglomerate overlying the iron belt, are often several feet in length, and angular. That these fragments prove the existence of the jaspery and chalcedonic material in its present condition before the formation of the quartzite is sufficiently evident."

N. H. Winchell,* to whom it appeared so great that the rocks above it were provisionally referred to the Potsdam. It has later been more broadly recognized by Prof. Alexander Winchell, who maintains two systems have been "confounded in the Huronian."†

Our recent studies have shown the break to be universal in the Marquette district. In order to understand fully its nature it is necessary that the facts shall be given in some detail. The greater part of the ore taken from the more prominent mines occurs associated with hematitic, magnetitic and actinolitic schists and jaspers. This jasper is curiously banded and contorted, is often of a beautiful blood-red color, and is commonly interlaminated with iron ores. Of prominent mines among many which fall in this horizon may be mentioned the Republic and Lake Superior. Below the iron-bearing member is the lower quartzite of Brooks, which locally becomes a marble or novaculite. Above the iron-bearing member is Brooks' upper quartzite.‡ This is in many places a pure thick quartzite which immediately overlies the ore. This quartzite, even when fine-grained, is of the variety in which the enlargement process has changed it from a sandstone to a vitreous quartzite. It shows nowhere any evidence of having been subjected to powerful dynamic action. It is at the base of this quartzite that the physical break referred to occurs.

At the Goodrich Mine, just south of a large open pit, is the banded ore and jasper formation which contained small bodies of rich ore. The formation is exceedingly contorted, the ribboning of the jasper now running in one direction, now in another. The foot-wall of the large pit just mentioned is this jaspery formation. Locally the banding of the jasper abuts perpendicularly against the foot-wall. This foot-wall strikes nearly in an east and west direction and dips at an angle of 60° or 70° toward the north. The rock resting upon the banded jasper, including that which has been mined for ore, is a conglomerate, the fragments of which are chiefly from the immediately underlying rock. These fragments vary from those which are minute, to bowlders ten inches or a foot in diameter. They are all thoroughly well rounded, so that there is no question of their water-worn character. As indicated, they are most abundantly of the jasper and ore immediately below, and the ore, upon account of its softer character, is predominant in the matrix. Mingled with the fragments mentioned are numerous ones of white quartz, which are

*Geol. and Nat. Hist. Survey of Minnesota, 16th Annual Report, 1887, pp. 43–47.

† "Two Systems confounded in the Huronian," Am. Geol., vol. iii, pp. 212–214.

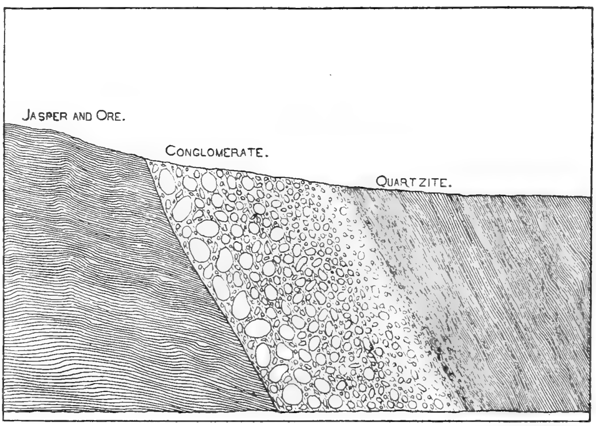
‡ Iron-Bearing Rocks of the Upper Peninsula of Michigan, T. B. Brooks: Mich. Geol. Survey, 1873, vol. 2, p. 149.

exactly like the white vein quartz found in the lower quartzite of Brooks and in the still lower granite-gneiss complex. The ore mined is here plainly a direct detrital product from the immediately underlying older formation.

Fig. 1.

The relations will be more clearly understood by Figs. 1 and 2. The first is from a photograph taken with the camera, pointing down upon the horizontal surface of the exposure. The manner in which the banded and contorted jasper abuts

Fig. 2.



against the conglomerate is clearly shown, as well as the irregular eroded surface of the jasper at the time the conglom-

erate was deposited upon it. Fig. 2. is a section from south to north, showing the relations described. The coarse conglomerate, in passing towards the north, varies into a fine conglomerate showing fragments of the same character, and this into the ordinary vitreous quartzite of the region.

Prof. N. H. Winchell's* figure of this mine does not show that he appreciated the manner in which the banded ore and jasper abut against the conglomerate. Its lamination is figured as regular and parallel to the foot-wall of the open pit, whereas it is extremely contorted and often abuts against it, while the conglomerate is represented as dipping at a flat angle away from the foot-wall, whereas the dip of the conglomerate is that of this wall.

In the Goodrich locality this conglomerate belt has been traced fully a mile east and west—that is, from the Saginaw Mine, east of the Goodrich, to the Fitch Mine a considerable distance west, and was noted by Brooks at the New England Mine, about two miles east of the Goodrich. The conglomerate, which is here so thick and prominent, is in most other localities in the Marquette district much thinner and varies quickly into the ordinary vitreous overlying quartzite, and has therefore often escaped attention. Upon searching for it, it has been found, however, almost everywhere in the Marquette district, as the following list of mines will show. At the Barron Mine near Humboldt, Mich., it is scarcely less conspicuous than in the Saginaw Range. It has been observed west of the Winthrop Mine; for a distance of a mile and a half or two miles along the Cascade Range, from the Cascade Mine to the Wheat; at the open pits of the Jackson Mine in Negaunee; at the Lake Superior and Barnum mines of the Ishpeming basin, as shown by diamond drill borings; at the Boston Mine, north of Clarksburgh, at the Spurr and Michigamme mines, near the west end of the Marquette Range; at the Republic Mine, the terminus of a long southern tongue of the iron-bearing series; and north of the east end of the Cascade Range, about $1\frac{1}{2}$ or 2 miles west of Goose Lake.

As pointed out by Professor Irving, since the fragments of ore, chert and jasper are found in the conglomerate in precisely the condition in which they occur in the underlying formation with their stratification lines running in every direction, it is manifest that the latter had reached its present condition before this overlying conglomerate was deposited.

Whatever the origin of this ore and jasper of the Marquette district is believed to be, it is evident that a time-break of universal extent and of great magnitude occurs above it.

* Geol. and Nat. Hist. Survey of Minn., 16th Annual Report, 1887, p. 46.

Above the upper quartzite, which is the base of the Upper Marquette Series, follow the black slates (sometimes carbonaceous), graywackes, and mica-schists, together of great thickness. These appear a short distance west of Negaunee; for some six or eight miles east of Lake Michigamme cover a larger area than the members of the series below the unconformity, and about Michigamme Lake have a great development. In these upper slates are locally belts of chert, associated with which are ore-bodies of considerable size, among which as types may be cited the Wetmore, Dalliba and Beaufort. These ores are, however, of a very different character from those which occur in the red banded jasper already described, being always soft, and oftentimes more or less limonitic. Our study has not extended far enough so that we feel certain on which side of the break some of the mines of the Marquette district occur. Among such are those of Teal Lake, which we feel inclined at present to place in the upper series.

It is thus plain that in the Marquette district we have, as maintained by Brooks, at least two ore-bearing horizons; not only this, but these horizons are separated by a great unconformity and therefore belong to different series of rocks. Those upon the lower side of this break, in the exceedingly contorted jasper, in the schistose character of its quartzites, and in the general assumption of a semi-crystalline character. show the evidence of profound dynamic action. In the upper series, on the contrary, the folding has not been intense; the fragmental character of the slates and quartzites under the microscope is evident at a glance, and no indication of great dynamic action is seen. While subsequent to the deposition of the upper series, the whole region has been subjected to a new folding, great enough in places to give the later series a dip of 60° or 70° as at the Goodrich, it has not suffered since that time such intense dynamic movements as has produced the more thoroughly crystalline and folded character of the earlier series.

Unconformity in the Vermilion Lake district.—Near Vermilion Lake, while we have not yet discovered the same structural evidence of a physical break between the iron-bearing and an overlying newer series, there occurs a wide belt of conglomerate which overlies the iron formation and contains very numerous fragments from that formation, as indicated by Irving in the paper already cited. A similar conglomerate, containing red jasper fragments and having a wide extent, occurs at Ogishki Manissi Lake.* This rock is also found at points intermediate between Vermilion Lake and Ogishki Manissi.

* Enlargements of Hornblende Fragments, C. R. Van Hise: this Journal, III, xxx, 232, 1885.

A short distance north of the Ogishki Manissi conglomerate, in Ontario, adjacent to Knife Lake on Hunter's Island, is the extension of the Vermilion Lake iron-bearing series, carrying large bodies of ore and jasper. That the iron-bearing series of Vermilion Lake and Hunter's Island are the source of the fragments found in these conglomerates there can be no doubt, and as the contained fragments are precisely like those found in the original position, there can be no question that the underlying series had reached its present condition before the deposition of the overlying conglomerate. We have here, then, very strong presumptive evidence of the existence of a considerable unconformity.

Unconformity in the Kaministiquia district.—Our recent work has shown that an exactly similar conglomerate is found very extensively developed in the neighborhood of Kaministiquia, Ontario. This is associated with a series of rocks which are the exact duplicate of the Vermilion Iron-Bearing Series. The reproduction in lithological phases is more perfect between these series than between any other detached series of rocks known to us in the Lake Superior region. The Ontario rocks have been subjected to folding so as to repeat the series, in this respect only differing from the Vermilion Lake rocks. The most abundant Kaministiquia rocks are the peculiar slates and schists, not easily described, but having characteristics easily recognized by any one who has studied the equivalent Minnesota series. These rocks, as at Vermilion Lake, contain abundantly the various phases of ore, chert and jasper well exposed at Tower and Ely and have an extent for many miles. The slates and schists are locally carbonaceous and graphitic as at Vermilion Lake, as for instance north of Port Arthur. The iron-bearing formation is in many places in its upper parts an iron carbonate which varies into ferruginous cherts and jaspers. These facts point to their derivation from an original cherty carbonate, as shown by Irving* to be probably true of

* Origin of the Ferruginous Schists and Iron Ores of the Lake Superior Region, R. D. Irving: this Journal, III, xxxii, 267–270, 1886.

Prof. N. H. Winchell and H. V. Winchell deny the derivation of the Vermilion ores from an original iron carbonate on account of the alleged lack in that district of this material. (On a Possible Chemical Origin of the Iron Ores of the Keewatin in Minnesota: Proc. Am. Assoc. Adv. Sci., 38th meeting, 1889, pp. 235–242; Am. Geol., vol iv, pp. 291–300, 1889.) That it is there found has already been shown by Irving, and the objection wholly falls to the ground in the Kaministiquia district.

Dr. M. E. Wadsworth maintains that the Lower Marquette ores and jaspers are eruptive. (Notes on the Geology of the Iron and Copper Districts: Bull. Mus. Comp. Zool., 1880, vol. vii, pp. 28–52.) Many facts are cited to show the way in which the jasper and ore intrude the associated schist or have irruptive contacts with it. The facts, however, indicate the eruptive character of the ore and jasper only if the schists are of sedimentary origin. Our later investigations have shown that the Lower Vermilion and Lower Marquette iron-bearing members contain many schistose dykes, and also that in many cases the massive greenstone

the Marquette, Vermilion Lake and other Lake Superior iron-bearing series. Here, as at Vermilion Lake and Hunter's Island the overlying conglomerate containing the jasper fragments has been derived from this underlying formation. We thus can separate the Vermilion, Hunter's Island and Kaministiquia iron-bearing and associated rocks into two series, an upper and a lower, just as we have been able to divide the Marquette series into two divisions.

Position of the Ogishki Manissi conglomerate.—If the foregoing is true, it determines the place of the Ogishki Manissi conglomerate. This has been placed by Dr. Alexander Winchell* as a part of the Vermilion Lake Iron-Bearing, that is, Lower Series. Professor N. H. Winchell,† having practically the same facts at his disposal has placed this conglomerate as probably belonging with the Animikie, and the associated slates have been given the same color as the Animikie formation on his map.‡

If, as argued above, the debris of the conglomerates is derived from the iron-bearing series after they have undergone profound changes, they do not belong with those series, but should be placed at an independent horizon or at the base of the Animikie. These conglomerates have been regarded by Mr. W. N. Merriam, who has done a very large amount of work in northeastern Minnesota, as a layer overlying the older formations. While the iron-bearing schists at Vermilion Lake are in a vertical attitude, the clastic layers of which the conglomerates are a part have been found on some of the islands of Vermilion Lake by Mr. Merriam to be gently folded into a series of rolls, although often having a vertical cleavage. We thus conclude, as has been thought by Irving, that at Ver-

knobs of the Marquette region vary by imperceptible stages into the schists associated with the iron ore and jasper. (The Iron Ores of the Penokee-Gogebic Series of Michigan and Wisconsin, C. R. Van Hise: this Journal, III, xxxvii, 32–48, 1889; the Greenstone Schist Areas of the Menominee and Marquette Regions of Michigan, George H. Williams: Bull. U. S. Geol Survey No. 62.) The schists are then, in part at least, of eruptive origin. That these well laminated rocks should not at first be regarded as eruptive is natural, but the variation of massive igneous rocks into those which are well laminated as a result of dynamic action and metasomatic changes is now so well known that new cases of it excite no surprise. I would by no means assert that all of the schistose rocks associated with the iron-ores and jaspers in the Marquette and Vermilion districts to be of eruptive origin, but this is certainly the case at many localities. This view reverses Dr. Wadsworth's and makes his sedimentary rocks eruptive and his eruptive ones sedimentary. It will, however, be seen that this position harmonizes Irving's conclusion as to the sedimentary origin of the ores and jaspers, and the point upon which Dr. Wadsworth places most emphasis, that there are irruptive contacts between these rocks and the associated schists.

* Geol. and Nat. Hist. Survey of Minnesota, 16th Ann. Rept., 1887, p. 359; Proc. Am. Assoc. Adv. Sci., 38th Meeting, pp. 234, 235.

† Geol. and Nat. Hist. Survey of Minnesota, 16th Ann. Rept., 1887, p. 98.

‡ Geol. and Nat. Hist. Survey of Minnesota, 15th Ann. Rept., 1886, pp. 208–209.

milion Lake and Ogishki Manissi Lake we have an infolded newer series resting upon older series of more crystalline rocks.*

Break below Lower Marquette Series.—It cannot be denied that the recognition of the break described disposes of some of the evidence which has been cited as proof of the break between the Lower Marquette and Lower Vermilion Series and the underlying complex.

Over large areas, by overlapping, the Upper Marquette Series of great thickness undoubtedly comes in contact with the Fundamental Complex. So far as local unconformities and basal conglomerates occur between these two, they only prove that the Upper Marquette Series is unconformably above the Fundamental Complex. Those who have held that the granite is later than the Marquette Series, and that the relations between the two are those described by Lawson between the Laurentian and Coutchiching, will undoubtedly gain support to an allied position by this fact, if so shifted as to maintain these relations between the Laurentian and Lower Marquette only. Since we cannot here enter into a discussion which would occupy much space, I can only state that it yet seems to us that there is sufficient evidence for the belief that the Lower Marquette Series rests unconformably upon the Fundamental Complex; while recognizing the fact that much of the granite is intrusive in certain "dioritic schists" which have usually been regarded as belonging to the Iron-Bearing Series.

The foregoing facts and relations in the Marquette, Vermilion and Kaministiquia districts once appreciated, it immediately occurs to one that here is a key which will harmonize apparently discordant opinions as to Lake Superior stratigraphy.

Relations of Animikie and Vermilion Series.—In the past few years the controversy has been most keen as to the equivalence or non-equivalence of the Animikie and Vermilion Lake Iron-Bearing Series. Professor Irving has maintained that the Animikie Series, in its lithological character, is like the Marquette, the Marquette like the Vermilion, and therefore the Animikie in all probability the equivalent of both Marquette and Vermilion.† Professor Alexander Winchell having visited

* Some Results of Archean Studies, Alexander Winchell: Bull. Geol. Soc. of America, vol. i, pp. 357–390; and Discussion, pp. 391–393.

† Prof. Irving perfectly appreciated that the Animikie Series rests in unconformity (On the Classification of the Early Cambrian and Pre-Cambrian Formations, R. D. Irving: U. S. Geol. Survey, 7th Ann. Rept., p. 421), upon their immediately underlying rocks, but believed that the weight of evidence to incline to the position that the Vermilion Lake iron-bearing series at some distance to the west is an infolded newer series now in apparent conformity with the older containing rocks, and that it is these latter which extend eastward and are found underlying the Animikie.

the Lower Marquette Series, and seeing but little of the ground in which the Upper Marquette is found, and consequently not appreciating that in area and in volume this series probably surpasses the Lower Marquette, has maintained that the Marquette rocks are the equivalent of the Vermilion Lake Iron-Bearing Series, but that the Animikie Series is separated from that at Vermilion Lake by a great unconformity. He, however, appreciated that in the Marquette district are certain slates which in lithological character are like and might be equivalent to the Animike.* Both of these positions probably have an element of truth and an element of error. The Upper Marquette, Upper Vermilion, Upper Hunter's Island (Ogishki Manissi), in their lithological characters and gentle folding, are closely analogous to the Animikie, and as maintained by Irving are its probable equivalent; while the Lower Marquette and Lower Vermilion Lake, as maintained by Professor Alexander Winchell, unconformably underlie the Animikie. Whether between the Kaministiquia and equivalent conglomerates, and the flat-lying rocks of the Thunder Bay district, recognized heretofore as Animikie, there is a minor physical break, we have no sufficient evidence to give an opinion. As has been noted, it has been long well known that near Port Arthur, Ontario, the Animikie and underlying Kaministiquia Series are unconformable. Mr. Peter McKellar,† who for many years has been familiar with this region, has proved this conclusively. It has already been seen that the rock series here unconformably underlying the Animikie are identical with the Vermilion Lake Iron-Bearing Series. Considering the complete likeness of this lower series with that bearing iron at Vermilion Lake, I can no longer have any doubt of the truthfulness of the conclusion as to the physical break between the Animikie and Lower Vermilion Series in northeastern Minnesota, while yet believing in the equivalence of the Animikie and Upper Vermilion.

Correlation, general considerations.—We pass now to the general correlation of the Lake Superior formation lying between the two planes defined at the beginning of this paper.

Before it can be decided whether series so far distant from each other as the Dakota quartzites and the Original Huronian (separated by 800 miles) can be parallelized, it ought to be more definitely settled to what extent correlation can be made by unconformities and lithological likenessess. Professor

* Geol. and Nat. Hist. Survey of Minnesota, 16th Ann. Rept., 1887, pp. 128, 357–359.

† The Correlation of the Animikie and Huronian Rocks of Lake Superior, Peter McKellar: Trans. Royal Soc., Can., vol. v, sec. 4, pp. 63–73, 1887.

Irving* inclined to the belief that such structural breaks as that described in the Marquette district are of great extent, and this accords with the general trend of modern structural work. From what has gone before it appears exceedingly probable that the structural break between the Upper and Lower Marquette is identical with that which separates, even in a more pronounced manner, the Animikie and Kaministiquia Series and the Upper and Lower Vermilion Lake Series on the other side of the Lake Superior basin. This break, being thus so strongly marked at points so far separated, would argue that it extends over a very considerable area of the Lake Superior region, not improbably from the most distant rock-series before mentioned, the Quartzites of Dakota and the Original Huronian of the north shore of Lake Huron. It could not be expected that a like succession would be found in each of the areas parallelized, even if they all belong to the same geological series. In the first place, the rocks in some districts are not sufficiently tilted to make it certain that all of the layers are exposed. Farther, nine-tenths or more of the surface of the country over large areas is heavily covered by the drift, so that it is all but certain that formations which exist at the rock surface have not been discovered. Still farther, no satisfactory explanation has yet been made of the subordinate succession of formations in the Marquette, Felch Mountain, Menominee and Vermilion Lake districts. So it is not yet known how far the order which prevails in one of the districts is equivalent with that which prevails in another. From recent work it is probable that future investigations will show that this likeness is greater in the series below correlated than has been suspected. But even supposing the discordances are so great as the present known facts might lead one to suppose, it would not be any very strong evidence against the correlations; for it is not to be expected that the same conditions of sedimentation would prevail at all times in a geological basin 800 miles in diameter. While in one part of the basin fragmental sediments were accumulating, it would be very strange if it were not the case that chemical sediments or organic sediments were elsewhere accumulating. Below it is shown that the Penokee and Animikie Series are the geological equivalents of each other in the broadest sense of the term. It is not necessarily true that sedimentation began or ended simultaneously in both regions, but only that in the main they stand as time equivalents. How far a correspondence can be made out among the subordinate members of the various districts can only be determined by a detailed investigation of each of the areas.

* On the Classification of the Early Cambrian and Pre-Cambrian Formations, R. D. Irving, U. S. Geol. Survey, Seventh Ann. Rept., p. 391.

The Original Huronian Series.—Passing now to the Original Huronian.* Shall this series be correlated with the Upper or Lower Marquette, or is it the equivalent of both? A careful field and laboratory study of the rocks of the Original Huronian has shown it to consist in great part (1) of fragmental quartzites, the induration of which has been caused by the deposition of interstitial silica; (2) of graywackes and graywacke-slates (at time, conglomeratic—Logan's slate-conglomerates), the induration of which is due to the deposition of interstitial silica and metasomatic changes in the feldspar; (3) of cherty limestones; and (4) of eruptives. So far as yet known an iron-bearing belt is not there largely developed, although at certain localities rocks belonging to this formation are found.

In its readily recognized fragmental character, in its gentle folding, and in the greatness of the break between it and the granite-gneiss complex, the Original Huronian is much more nearly analogous to the Penokee, Upper Marquette and Animikie than to the Lower Marquette and Lower Vermilion iron-bearing series. In the order of succession of its subordinate members it cannot be said to correspond very closely with either the Upper Marquette and Animikie or the Lower Marquette and Lower Vermilion Lake. It, however, seems to us that its unmetamorphosed character is a guide of some importance. As pointed out by Mr. McKellar,† the intense folding to which the Vermilion Lake and Kaministiquia Series have been subjected must have preceded the much more gentle synclinal movement which formed the basin of Lake Superior. That no violent squeezing has occurred since the beginning of Animikie time is known to be true of the Lake Superior Basin, and this being true, it seems exceedingly probable that the gently folded rocks of Lake Huron belong with those of like character about Lake Superior. If this is not the case, the intense dynamic movements which produced the closely folded rocks of Northeastern Minnesota and Ontario must have lost their force before reaching the area about Lake Huron, and this region must have escaped any serious folding for a longer time than any other closely studied part of the earth's crust.

* The Original Huronian only is here compared with the series about Lake Superior because it is the area to which the term was first applied, and also because it has been more thoroughly described and mapped than any other area in Canada designated by the term Huronian. How far other areas of rocks included under this term by the Canadian Survey in the past are the equivalent of this Original Huronian area is difficult to determine. That many other areas are less Huronian than the original area I would not pretend to say. In this connection see, The Huronian System in Canada, by Robert Bell, Trans. Royal Soc. Can., vol. vi, sec. 4, pp. 3–13, 1888.

† L. c. p. 88.

Besides the reason already mentioned for placing the Huronian as the equivalent of the Animikie and Upper Marquette rather than below these series, we have one characteristic feature which is of some weight.

One of the most peculiar rocks of the Original Huronian is a conglomerate which carries numerous fragments of blood-red jasper. At present the source of these fragments is unknown. From what has gone before it is apparent that a jasper conglomerate is the basal member of the Upper Marquette Series, and also that similar conglomerates occur in a like position in Ontario and northeastern Minnesota. Considering the widespread character of this jaspery, cherty and iron ore conglomerate, its occurrence in the Huronian of Lake Huron suggests that here may be found in the future an underlying series which bears this jasper in large quantity and which therefore will in position and in lithological character, be the equivalent of the Lower Vermilion and Lower Marquette iron-bearing series.*

In this connection it is to be said that Mr. McKellar, in the article already cited, argues that the Animikie is newer than the Original Huronian because of the great unconformity which maintains between the Animikie series and the underlying schists of western Ontario which he regards as Huronian. The weak point of this argument is the assumption that those underlying schists are more nearly like the Original Huronian than are the Animikie rocks. The author states that he has not himself closely studied the Original Huronian, while the later writers who have visited both regions, including Prof. Irving and the Profs. Winchell, agree that the Original Huronian is far more nearly alike, both in essential lithological character and in conditions of metamorphism, to the Animikie series, than to the folded schists of Canada and Vermilion Lake iron-bearing rocks, and with this view our later work work accords.

The Sioux Quartzites, St. Louis Slates, etc.—Much of what has been said to show that the Original Huronian is the equivalent of the Animikie, Upper Vermilion and Upper Marquette applies with equal force to such rock series as the Chippewa Quartzites, the Baraboo Quartzites, the Sioux Quartzites and the St. Louis Slates. None of these series are closely folded although often, dynamic movements have developed slaty cleavages. Also their original fragmental character is seen under

* Since this paper was written, Alexander Winchell has announced the discovery of an unconformity in the Original Huronian area, the "Lower Slate Conglomerate" belonging below the break, although no contacts are described. If this conclusion is correct, we have here as in other districts two series above the fundamental complex and the analogy is complete (Am. Geol., vol. vi, p. 370).

the microscope at a glance. These series present thick beds of fragmental rocks, the induation of which has been caused by the same process which vitrified the quartzites of the Original Huronian. The supposed absence of ferruginous rocks in these districts has been used in the past as an argument against the correlation of them with the Penokee and Animikie Series below considered, but this absence has no particular weight because such beds, as compared with the fragmental rocks, are insignificant in amount; and farther, it is quite possible that such non-fragmental water-deposited formations may in the future be found in several or all of these districts. The probability of this is rendered greater by the fact that explorations for iron have very recently developed beds of this sort between the two quartzite ranges of Baraboo and in the northward extension of the St. Louis Slates. The rocks here found are the exact parallel of the iron-bearing beds of the Penokee and other iron-bearing districts. The percentage of iron is so great in certain localities that the material is being mined for an ore.

The Penokee-Gogebic and Animikie Series.—In the Penokee-Gogebic district of Michigan and Wisconsin we have the following succession: At the base is a gneiss-granite schist complex. The schists are always completely crystalline, although often finely laminated or foliated. The contact of the granites and granite-gneisses with the crystalline schists is the irruptive one so well described by Lawson as prevailing in Ontario. Above this granite-gneiss-schist complex, and separated from it by a great unconformity, is a Cherty Limestone Member which in places is 300 feet thick. While it extends east and west many miles, it is not longitudinally continuous. Above this cherty limestone, separated by an erosion interval, is the Penokee-Gogebic series proper, which consists of a Quartz-Slate Member, the upper horizon of which is a vitreous quartzite, an Iron-Bearing Member, and Upper Slate Member. Above the Penokee series, separated by another very considerable unconformity, is the Keweenawan Series. The parallelism between this region and the Marquette already described is at once manifest. The Penokee series proper is the equivalent of the Original Huronian, Upper Marquette and their equivalents: The Cherty Limestone Member stands as a possible equivalent of the Lower Marquette. But this correlation is of uncertain value, and, if sound, in the Penokee-Gogebic district the upper members of the equivalent of the Lower Marquette have been removed by erosion. That this is not improbable is indicated by the fact that the cherty limestone is of very considerable thickness in some places and has entirely disappeared in others, while numerous fragments of it are found in the basal member of the Penokee series proper.

Farther, the relative geographical positions of the Penokee, the Upper Marquette and the Chippewa Quartzite districts are such as to strongly suggest that they were once connected. The Penokee Series at the east is cut off by the unconformably overlying Eastern Sandstone; but east of the south end of Gogebic Lake there are here and there outcrops of slate which are like the Upper Slate Member of Penokee district, and a short distance to the east the narrow belt spreads out into the broad area of fragmental rocks of which the Marquette and Menominee districts are arms. At the west the Penokee Series has been entirely swept away by erosion, the copper-bearing rocks coming in contact with the underlying gneisses and granites; but to the southwestward appears the fragmental quartzites of the Chippewa valley which are believed to be its continuation.

The equivalency of the Penokee Series with the Animikie is as plain as the equivalency of any two areas of detached rocks in a single geological basin can possibly be in which is lacking clear paleontological evidence. It has been seen that above the Cherty Limestone of the Penokee Series is an erosion interval. In the Animikie Series we know of no equivalent to this member, and in what follows it is excluded from the discussion. The Penokee and the Animikie rocks have a parallelism in lithological characters which is most remarkable. Not only is there a general likeness between the specimens from the two districts, but almost every phase of rock from the Animikie Series can be matched by specimens from the Penokee district. In the Animikie district the formations underlying the iron-bearing belt are not extensively exposed, and consequently little is known of the Animikie equivalent of the Quartz-Slate of the Penokee Series. But along the Lower Current River, near Port Arthur, Ontario, quartz-slates underlying the Iron-Bearing Member are found, which resemble certain phases of the Penokee Quartz-Slate. Beginning with the iron-formations, the parallelism between the two series is almost exact. The irony beds upon Gunflint Lake, where are found the best known exposures of the formation, are in their lower parts jasper, magnetite-actinolite-schist, and cherty ferruginous rocks containing more or less iron carbonate. Higher up are thick layers of thinly bedded cherty iron carbonate. All these varieties of rock are found in the iron-formation of the Penokee Series, and at many places the order of succession is the same. Above the iron-bearing belt in both regions is a great thickness of fragmental clay-slates and greywacke-slates which are again practically identical in character in both districts. It is true that in the western part

of the Penokee district mica-schists have developed from these slates, but the original condition of these rocks was essentially like that of the unaltered phases.*

Underlying both the Animikie and the Penokee Series is a complex of granites and schists, the unconformity between which and these series is of the most pronounced character. That the Animikie Series is thus separated from the underlying rocks has been seen by all who have studied it. Above both series follow the Keweenaw rocks. In both regions, in passing at any place from the underlying rocks to the Keweenaw Series in section, the two are in apparent conformity; but, when the lines of contacts between the iron-bearing and the Keweenaw series are followed for some distance, both with the Animikie and Penokee series, this apparent conformity is found to be illusory. That is, the same member of the Keweenaw Series is now found to come in contact with one member of the underlying series and now with another, until in both regions at one or more places the entire Iron-Bearing Series is cut off, the Keweenaw rocks coming directly in contact with the basement complex.† This means that between the deposition of the Penokee and Animikie Series and the outflows of Keweenaw time there intervened a period of erosion which was sufficient in places to remove the whole of the inferior series and to cut in some places quite deeply into the Fundamental Complex. There is then an immense time-gap between these series and the overlying Keweenaw rocks, although this unconformity does not approach in the length of time involved to that separating them from the underlying schists and granites.

The Animikie Series in its most typical development extend from Gunflint Lake, on the National Boundary between Minnesota and Ontario, to Thunder Bay, Lake Superior. The Penokee Series lies upon the opposite side of Lake Superior. The latter is a simple unfolded succession dipping to the northward under the lake; the Animikie is another such succession dipping to the southward under the same body of water. There is then little doubt, considering all the facts, that the two series represent a single period in the geological history of Lake Superior. The relations and likeness of the Penokee and the Animikie Series have been dwelt upon at length as showing the breadth of the geological basin in which the deposition of like rocks was taking place simultaneously.

* Upon the Origin of the Mica-Schists and Black Mica-Slates of the Penokee-Gogebic Iron-Bearing Series, C. R. Van Hise: this Journal, III, xxxi, 453-459, 1886.

† For full discussion of the proof of the unconformity between the Animikie and Keweenaw Series, see On the Classification of the Early Cambrian and Pre-Cambrian Formations, R. D. Irving: 7th Ann. Rept., U. S. Geol. Survey, pp. 417-423.

The equivalency here shown is a long step in understanding the equivalency of other rocks in the Lake Superior basin.

The Marquette Series.—As in the Marquette district we have already discussed in a general way the succession, it need here be merely repeated. It is as follows: At the base is a gneiss-granite complex, Lawson's Laurentian, and this is associated with crystalline schists which are like Lawson's Coutchiching. The relations between these two classes are also those described as occurring between them in Ontario. In ascending order follow the Lower and Upper Marquette, having the lithological characters and relations above described.

The Menominee and Felch Mountain Series.—Passing now to the Menominee and Felch Mountain districts, our information is less exact. It is, however, clear that in both of these areas we have the Fundamental Complex; that is, the granites and gneisses associated with crystalline schists having the usual "irruptive contacts"—the equivalents in every respect of Lawson's combined Laurentian and Coutchiching. Above this complex Prof. Pumpelly, with whom this whole subject has been discussed and who has great familiarity with the entire Lake Superior region, suggests as exceedingly probable that in the Felch Mountain Iron-Bearing Series only the equivalent of the Lower Marquette occurs, the upper series, if it once existed, having been removed by erosion; while in the Menominee district both representatives of the Lower and Upper Marquette are present. The Menominee proper—that is, that part of the area which includes the Chapin, Ludington and Norway mines; those in which a cherty limestone is found—are Lower Marquette, while the western district, including such mines as the Commonwealth, Florence and many others occurring in the upper black slate are Upper Marquette. That between these two is an unconformity is not proven, but it is a probability to be sought.

The Black River Falls Series.—The Black River Falls Iron-Bearing Schists of Wisconsin have no such structural relations as to enable one to determine their position. They are, however, thoroughly crystalline schists and are in vertical attitude. On these grounds they are placed as the equivalent of the Lower Marquette.

In the districts about the Lake of the Woods and Rainy Lake, so well described by Lawson,* we have apparently, as at Felch Mountain only the two lower series of the general succession, the Coutchiching-Laurentian complex; and above this

* Report on the Geology of the Lake of the Woods Region, Andrew C. Lawson, Geol. and Nat. Hist. Survey of Canada, Ann. Rept. 1885, vol. 1, new series, part CC, pp. 1–151. Report on the Geology of the Rainy Lake Region, Andrew C. Lawson: Geol. and Nat. Hist. Survey of Canada, Ann. Rept. 1887, part F, pp. 1–190.

the Keewatin—probable equivalent of the Lower Marquette. It, however, appears that in this part of Ontario somewhat different conditions prevail from those which occur on the south shore of Lake Superior. The irruptive contact found between the Coutchiching and Laurentian is also present between the Laurentian and Keewatin. Upon the south shore it does not appear that granitic eruptions of any magnitude have taken place since the beginning of Lower Marquette time, although in the Felch Mountain Iron-Bearing Series occurs one granitic dyke of considerable size, and it is not impossible that in the Marquette district itself some of the lower members truly belonging to the iron series are cut by granitic eruptions.

We then have in the Lake Superior region the provisional arrangement for the Pre-Cambrian rocks on page 137.

Nomenclature.—There still remains the question of nomenclature. A sufficient number of terms have been suggested, and it is only necessary to ascertain which have prior right and best answer the needs of geology. The work of Lawson has made it clear that the old Laurentian must be subdivided. He retains for the igneous portion of it Laurentian, and proposes for the lower crystalline schist series—which he supposes to be fragmental, but which if so in most cases does not now reveal at all its original clastic character—the term Coutchiching. The rock series represented by these terms, as has been seen, cover large areas in Minnesota, Michigan, and Wisconsin, and the relations between the two are here the same as in Ontario. It then seems desirable to apply them broadly to the Fundamental Complex of the south as well as the north shore of Lake Superior. The only other term introduced for this part of the column is the Vermilion Series, equivalent to Coutchiching, proposed by the Professors Winchell. The latter term has, however, unquestionable priority and has been more definitely defined.*

The term Keewatin was defined by Lawson to cover a series of clastics about the Lake of the Woods, and was chosen by the Professors Winchell for the Vermilion Lake iron-bearing series, which was believed by them to be the equivalent of the Original Keewatin. If this conclusion were demonstrated, it would seem proper to adopt this term to cover not only the

* In this article, Vermilion Series always refers to the iron-bearing rocks and associated clastics of Vermilion Lake. This term was thus first loosely applied by Irving (Preliminary Paper on an Investigation of the Archean Formations of the Northwestern States, R. D. Irving: 5th Ann. Report, U. S. Geol. Survey, pp. 177–242.) Later it was used by the Professors Winchell to designate an underlying series of crystalline schists. For this series, however, Lawson had previously proposed the term Coutchiching. (The Internal Relations and Taxonomy of the Archean of Central Canada, Andrew C. Lawson, Bull. Geol. Soc. of America, vol. i, p. 183, 1890.)

series in these districts, but the Lower Marquette, Lower Vermilion, Hunter's Island and Lower Kaministiqua series. It is, however, by no means clear that the Keewatin will not prove to be a complex series just as have the Marquette and Vermilion Lake rocks. One other term has been proposed for this place, Marquettian,* but this term is objectionable because as used it included both Upper and Lower Marquette. Dr. Selwyn very strongly maintains that Huronian as used by the Canadian Survey includes not only the rocks designated in this paper under the term Original Huronian, but also all such series as the Keewatin, Lower Marquette, and Lower Vermilion Lake. This also accords with what has been done on the United States side of the boundary in the past, so that for the position in the general column below the Original Huronian is used Lower Huronian.

Mr. Lawson† has proposed Ontarian to cover the Keewatin and Coutchiching. It appears to us that this term is unnecessary, and that the purposes of geology are better subserved by using the term Algonkian to cover all the clastic series between the Fundamental Complex and the Cambrian, and to retain Archean as a term of coördinate value with this for the underlying complex.

Dr. Selwyn and Professor N. H. Winchell maintain‡ that the Keweenawan and Animikie are properly Cambrian. Whether the term Cambrian shall be so extended downward as to cover two great unconformities and two additional rock series of very great thickness is purely a matter of policy and of nomenclature. While it is of primary importance that an agreement shall be reached as to the actual rock successions in the Lake Superior region and their equivalence, it is but a secondary matter as to the names which shall be applied to them. That fossils are found in the Huronian is not sufficient evidence that the Cambrian shall be extended downward indefinitely. That the evidences of abundant life are here found has been long known. Many of the slates heretofore called Huronian on the south shore of Lake Superior not only contain graphitic material, but a considerable percentage of hydrocarbons. In the Animikie, on the north shore of Lake Superior, it is said that in certain mines and openings rock gas forms in consider-

* Geol. and Nat. Hist. Survey of Minn., 16th Ann. Rept., 1887, pp. 365, 366.

† The Internal Relations and Taxonomy of the Archean of Central Canada, Andrew C. Lawson, Bull. Geol. Soc. of America, vol. i, pp. 175–193, 1890.

U. S. Geol. Survey, 10th Ann. Rept., Report of the Director.

The Pre-Cambrian Rocks of the Black Hills, C. R. Van Hise, Bull. Geol. Soc. of America, vol. i, foot-note p. 238, 1890.

‡ Tracks of organic origin in rocks of the Animikie group, A. R. C. Selwyn: this Journal, III, xxxix, 145–147, 1890, with Geol. and Nat. Hist. Survey of Minn., 17th Annual Report, 1888, p. 68.

able amount. Also small quantities of rock may even be obtained which will burn. These substances must result from the ordinary processes which produced rock gas and coal in the rocks of far later age. In the Sioux quartzites one unquestionable fossil has been discovered by Professor N. H. Winchell:* a discovery of a fossil has been announced by Dr. Selwyn† as occurring in the Animikie. It is a hope that in the future numerous other fossils will be found in these series, so that we may have the assistance of paleontology in Lake Superior stratigraphy. Until, however, a fauna is known in this region which is distinctly Cambrian, the discovery of life or of certain fossils in the Keweenawan and Huronian rocks is wholly insufficient evidence for placing them with the Cambrian. The Cambrian fauna in development is fully half way up the life column. Just as another period of life has succeeded the Cambrian, another has preceded it. The progress of paleontological knowledge has of late been downward. Before there was a recognized Cambrian there was a well known Silurian, and it is probable that as we become familiar with all parts of the world, other faunæ will be discovered below the Cambrian as distinctive in character as the Cambrian is from the Silurian. When this is done, we shall have definite means to correlate rock series which occur in different parts of the world in the great time place represented by the Algonkian.‡

I have no expectation that the above provisional succession and correlation for the Lake Superior region will prove to be accurate in all details. To a certain extent it is based upon a large number of facts and may be considered as true with a reasonable degree of probability. Another part is based upon facts of a more general nature and therefore has a corresponding uncertainty. It is, however, believed that there is in reality a much greater degree of harmony than has been thought in the conclusions which the various writers have held most steadfastly as to Lake Superior stratigraphy.

* Geol. and Nat. History Survey of Minn., 13th Annual Report, 1884, pp. 68–72.

† Tracks of Organic Origin in rocks of the Animikie group, A. R. C. Selwyn: this Journal. III, xxxix, 145–147, 1890.

‡ For a fuller discussion of the subject of this paragraph see "On the Classification of the Early Cambrian and Pre-Cambrian Formations." R. D. Irving, U. S. Geol. Survey, 7th Ann. Rept., pp. 448–454.

		Western Ontario.	*Northern Minnesota.	Michigan.			Michigan and Wisconsin.	Wisconsin.	Iowa, South Dakota and Southern Minnesota.
				Marquette.	Felch Mountain.	Menominee.	†Penokee-Gogebic.		
Algonkian.	Keweenawan.	Nipigon.	Keweenawan.				Keweenawan.	Keweenawan.	
	Unconformity.	Unconformity.	Unconformity.				Unconformity.	Unconformity.	
	Upper (Original) Huronian.	Animikie and Upper Kaministiquia.	Animikie and Upper Vermilion.	Upper Marquette.		Western Menominee.	Penokee-Gogebic Proper.	Chippewa Quartzites. Baraboo Quartzites.	Minnesota and Dakota Quartzites, surrounded by fossiliferous series.
	Unconformity.	Unconformity.	Unconformity.	Unconformity.		Inferred Unconformity.	Erosion Interval.	Unconformity.	
	Lower Huronian.	Keewatin in part at least, and Lower Kaministiquia.	Lower Vermilion.	Lower Marquette.	Felch Mountain Iron-Bearing Series.	Menominee Proper.	Cherty Limestone (?)	Black River Falls Iron-Bearing Schists (?)	
	Unconformity.	Unconformity?	Unconformity ?	Unconformity.	Unconformity.	Unconformity.	Unconformity.	Unconformity (?)	
Archean.	Coutchiching.	Coutchiching.	Coutchiching.	Fundamental Complex. (Not yet separated in mapping.)	Fundamental Complex (Not yet separated in mapping.)	Fundamental Complex. (Not yet separated in mapping.)	Southern Complex. (Separated in mapping into fine-grained schist, Coutchiching, and granites and granite-gneisses, Laurentian, showing characteristic irruptive contact.	Fundamental Complex. (Not yet separated in mapping.)	Minnesota River Valley Gneiss and Granite.
	Eruptive Unconformity.	Eruptive Unconformity.	Eruptive Unconformity.						
	Laurentian.	Laurentian.	Laurentian.						

* This succession is analogous to that given by Dr. Alexander Winchell (Some Results of Archean Studies, Alexander Winchell; Bull. Geol. Soc of America, 1890, vol. i, p. 389), except that the great Vermilion and Ogishki series of slates and conglomerates would be placed by him in the Keewatin. Vermilion series as we use it applies to the iron-bearing and associated rocks, while the crystalline schists are designated by Coutchiching.

† The Penokee Iron-Bearing Series of Michigan and Wisconsin, R. D. Irving and C. R. Van Hise. Monograph 16 U. S. Geol. Survey; Abstract of same, 10th Ann. Rept. U. S. Geol. Survey.

ART. XVII.—*Powellite—Calcium Molybdate: A new mineral Species;* by W. H. MELVILLE.

ATTENTION has been recently called in mining journals to a locality in the western part of Idaho known as the "Seven Devils" where mining operations for some time past have been actively conducted. "The 'Seven Devils' about ninety miles due north of Huntington and fifteen miles east of Snake River form a high broken chain of mountains nearly 9,000 feet above the sea level. The mineral zone is about one mile wide by four miles in length."* The ore is worked for copper and silver, and is mainly the mineral bornite, a sulphide of copper and iron. "The formation on the west of the vein of ore is syenite and quartzite, while on the east wall is a soft white granite. A short distance to the east is a lime contact which extends south for some four miles, and forms a contact with granite. Along this contact some very good chimneys of ore have been discovered."

This bornite carries silver varying in quantity from 12 to 20 ounces to the ton. In one sample of very pure bornite Mr. R. L. Packard found by assay 14 ounces of silver to the ton. A sample from which I had separated for the most part the other mineral constituents gave me 15·65 ounces of silver to the ton. It was this latter fragment of bornite, weighing about 60 grams, which Mr. Packard picked up from a dump before one of the tunnels in the mining claim called Peacock and which through this gentleman's kindness furnished the material for this paper. The specimen had evidently been exposed to weathering processes and had become friable to such an extent that between the fingers it could be crushed by slight pressure.

There were two associated minerals, one of which was identified by the following partial analysis as a lime-alumina iron garnet. It was light brown, but not crystallized. It fused easily to a black glass.

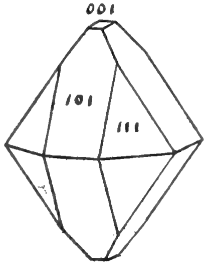
Loss on ignition	0·06 per ct.
SiO_2	38·67
Al_2O_3	10·08
Fe_2O_3	16·00
FeO	0·91
CaO	33·35
MgO	0·77
CuO	trace
	99·84

* Quotations from Engineering and Mining Journal, Nov. 22, 1890.

Crystallized dark brown garnet is found in considerable abundance throughout this locality. The crystals exhibit the usual combination of rhombic dodecahedron and tetragonal trisoctahedron.

That which proved to be the most important constituent of the specimen, about 1·5 grams, somewhat resembled scheelite at first sight, but a careful study of its characters excluded that mineral species from consideration. The strong reactions for molybdenum suggested a new species. The mineral was well crystallized and easily detached in almost absolutely pure condition from its friable matrix. Angular measurements were obtained on a number of crystals, from which the crystallographic elements were calculated. The fundamental angle (111) ∧ (11$\bar{1}$) was chosen because of its great accuracy, the signals on the goniometer being perfectly reflected from these planes. Other angles were read oftentimes between reflected signal and reflected light, and again between merely reflected light from the crystal faces. The best crystals were about 0·04 (1^{mm}) long, and others attained the maximum length of 0·10 inch. It was found that the crystals belonged to the pyramidal (tetragonal) system of crystallization, and were closely allied in habit and development to scheelite. In the following table of measurements this analogy is shown.

1.



	Powellite.		Scheelite.*
$a:c$	1 : 1·5445		1 : 1·5369
Between normals.	Observed.	Calculated.	
111 ∧ 11$\bar{1}$	49° 12′	fundamental	49° 27′
111 ∧ 001	65° 24′	65° 24′	65° 16′
111 ∧ 1$\bar{1}$1	79° 56$\frac{4}{5}$′	80° 1′	79° 56′
101 ∧ 10$\bar{1}$	65° 55′	65° 51′	66° 6′
101 ∧ 111	40° 1$\frac{1}{2}$′	40° 1′	39° 58′

From this comparison of angles and axial ratio it is evident that sharp and accurate observations must be obtained in order to distinguish by crystallographic means alone between these two species. Many crystals were examined and many trials were necessary before any difference in these angles from those of scheelite could be made out.

The following forms were observed: $\{001\}\ \infty a : \infty a : c$
$\{111\}\ a : a : c$
$\{101\}\ a : \infty a : c$
$\{110\}\ a : a : \infty c$

Small rudimentary planes appear on some crystals at the lower portion of the combination edges (111) (101), thus sug-

* Dana's System of Mineralogy, 1883, p. 605.

gesting hemihedrism as in scheelite. Indeed the curved surface which often replaces these edges, giving the appearance of fused edges, adds greatly to the evidence in favor of this supposition.

No cleavage planes could be developed by mechanical means, yet occasionally fragments exhibited interrupted planes similar to cleavage surfaces. Hardness less than scheelite, about 3·5. Sp. gr. 4·526, mean of two determinations. Color yellow with a decided green tinge. Luster resinous. Crystals semi-transparent. Brittle. The blowpipe characters are those ordinarily given under molybdates and tungstates, although the reactions of molybdenum in this case obscure those of tungsten associated with it. The mineral fuses at about 5 to a gray mass. Decomposed by nitric and hydrochloric acids.

With Powellite was associated an olive-green substance which without doubt resulted from the decomposition of calcium molybdate perhaps by water holding carbonic acid in solution, whereby molybdic ochre was formed.

The following analysis shows the unusual replacement of a part of the molybdic acid by tungstic acid. Rose's method of separating these acids was adopted, and abundant tests proved the purity of the respective products of separation. Molybdenum trisulphide was collected by reverse filtration and aliquot portions were taken for reduction. The molybdenum was weighed first as disulphide, and this weight was checked by reduction to metal in hydrogen gas by strong and long continued ignition. Mercurous tungstate was precipitated, then ignited, and tungstic acid was finally weighed.

ANALYSIS OF POWELLITE.

		CaO required.
MoO_3	58·58%	22·79
WO_3	10·28	2·48
SiO_2	3·25	
CaO	25·55	25·28
MgO	0·16	
Fe_2O_3	1·65	
Al_2O_3	trace	
CuO	trace	
S	undetermined	
	99·47 %	

Calcium molybdate has never before been observed in nature, and although the mineral under discussion contains some calcium tungstate,—according to analysis a little less than one molecule to eight molecules of calcium molybdate,—yet the molybdate is now established as a species. It fills a gap heretofore existing in the series of isomorphous minerals

of which scheelite is the type. If the natural molybdate and tungstate of lime have the same molecular volume as is most probable, then the sp. gr. of pure $CaMoO_4$ should be $200 \div 46{\cdot}9 = 4{\cdot}267$, if the molecular volume, $288 \div 6{\cdot}14 = 46{\cdot}9$, is true for scheelite. By means of the equation for the determination of the sp. gr. of one constituent of a mixture containing two substances of which one is known, the sp. gr. of $CaMoO_4$ is 4·3465 assuming the sp. gr. of $CaWO_4$ to be 6·14 and that of the mixture 4·526 (sp. gr. of powellite). This close agreement in these two calculations of the sp. gr. of $CaMoO_4$ is an interesting and important confirmation of the chemical and physical data which are given above.

When this investigation was nearly completed my attention was called to a recent paper by H. Traube* in which was discussed the influence of certain varying quantities of molybdic acid in scheelite upon the physical constants, namely, sp. gr. and axial ratio. The following scheme is interesting in that it illustrates those variations which different proportions of isomorphous mixtures of $CaWO_4$ and $CaMoO_4$ produce. No mathematical law seems to exist which will express these transitions.

	$CaMoO_4$	Powellite	Scheelite			$CaWO_4$
			S. W. Africa.	Zinnwald.		
				(1)	(2)	
% MoO_3	72	58·58	8·09 7·63	8·23	1·92	O
Sp. gr.	4·267	4·526	5·96	5·88	6·06	6·14
$a:c$	1 : 1·5458†	1 : 1·5445‡			1 : 1·5349†	1 : 1·5315

I take pleasure in naming this new mineral species in honor of Major J. W. Powell, Director of the United States Geological Survey.

Chemical Laboratory of the U. S. Geological Survey, Washington, D. C., December 11th, 1890.

Art. XVIII.—*Brückner's Klimaschwankungen;* by Frank Waldo.

Dr. Edward Brückner, the youthful professor of Physical Geography at the University of Berne, has devoted three years to the gathering together and discussion of data concerning oscillations of climate as shown by direct observations

* Neues Jahrbuch für Mineralogie, Beilage-Band, vii, Heft 2, 1890.
† 1. Th. Hiortdahl, Zeitschr. f. Kryst. xii, 413, 1887.
‡ Neues Jahrbuch, Beilage-Band, vii.

instituted by man. His book,* which contains the results of his investigation, is a real contribution to the steady advancement of our knowledge of the subject, and is not merely the working out of a theory based upon an hypothesis which may be at any time overthrown by new discoveries or new ideas. The amount of work necessary to present the matter in the shape given by Dr. Brückner can be judged only by those who have undertaken researches of the same nature, but, as may confidently be said, of less extent. The sub-topics of the book are:

Chapter I. The present condition of the question. Chapt. II. Oscillations of the Caspian Sea. Chapt. III. The secular oscillations of lakes having no outlet. Chapt. IV. The secular oscillations of rivers and lakes with outlets. Chapt. V. Secular oscillations of rain-fall. Chapt. VI. Secular oscillations of air-pressure. Chapt. VII. Secular oscillations of temperature. Chapt. VIII. Periodicity of oscillations of climate, derived from observations of river ice, dates of the grape harvest, and the frequency of severe winters. Chapt. IX. The significance of oscillations of climate for theoretical and practical purposes. Chapt. X. Oscillations of climate of diluvial times. Review of the results obtained. Graphical presentations.

In the general statement of the work that had been previously done, as given in Chapt. I, we obtain a good idea of the extent of the preliminary work done by the author in preparing for his own investigations. The most important literature is certainly embraced in the several hundred titles referred to, and the very condensed summary of the main results of each (pertaining to the question under discussion) shows a good grasp of the matter. In some cases, however, minor and comparatively unimportant contributions are mentioned with the same degree of deference as that given to very exhaustive pieces of work, and without an actual reference to the works themselves the reader may be misled into giving too much weight to the contradictions of the latter by the former.

In carrying out his own work, Dr. Brückner has given most valuable critical opinions of the materials and studies on which he has based his researches; and his estimates of their individual worth are the results of painstaking and in most cases time-consuming investigations.

As a final table of the oscillations of the surface of the Caspian Sea, Brückner gives:

* Klimaschwankungen seit 1700 von Dr. Eduard Brückner, Penck's Geographische Abhandlungen, Band IV, Heft 2, Wien, 1890, (Ed. Hölzel.)

Year.	Amount in Meters.	Year.	Amount in Meters.
		1830	+ ·40
915/21	+ 8·8	1843/46	−0·59 under this.
12 century	— 4·2	1847	+0·22 higher than this,
1306/07	+11·2		falling 1809/14–1845
1638	+ 4·9	1851/55	−0·21 falling 1847–1856/60
1715/20	about + 0·3	1856/60	−0·27 rising 1845–1847
1715/43	rising	1861/65	—0·19
1744/66	falling	1866/70	+0·19 rising 1866–1878
1767/80	rising (?)	1871/75	+0·17
1815	+ 2·40 at least	1876/78	+0·54

1730/40 to 1809/14,
a relatively high level.

There are, consequently, maxima about 1743, between 1780–1809 and 1847–1879; and minima about 1715, 1766, 1845 and 1856–60. Brückner places the average duration of an oscillation at about 34 to 36 years. That these oscillations are due to large sectional climatic influences is very evident. A comparison with the oscillations of rainfall and temperature shows that for the period since 1840, these are accompanied by oscillations in this sea level.

For the region west and north of the Caspian Sea, there occurred wet, cold periods about 1745, 1775, 1810, 1845, 1880; and dry, warmer periods about 1715, 1760, 1795, 1825, 1860. These changes affect the inflowing rivers, which in turn change the level of the sea. A comparison with the table of sea levels shows the increase with cold, wet periods and decrease with the dry, warm periods. There are long periods of oscillations in addition to the short period fluctuations.

An investigation of a number of lakes gave the following results:

(1.) The oscillations of the true river-lakes are small and follow without retardation the river oscillations.

(2.) The oscillations of lakes having no outlet are large, and the epochs show a retardation in relation to the corresponding epochs of the inflowing streams: the maximum height of the lake may occur at the time the receding inflowing streams have reached an average height.

(3.) Lakes having no outlets have a slighter retardation in the case where the inflowing streams have large oscillations than for those where the oscillations are small; and the same is true of lakes with low banks in contrast with those having high banks.

(4.) Small secondary oscillations of the influx in lakes having no outlet are without marked effect when the difference of the inflow and diminution still retains the same sign. The only effect is to accelerate or retard the rise or fall of the water.

(5.) In these particulars the partial river-lakes stand somewhere between the true river-lakes and the lakes without outlet.

A list of the times of maxima and minima before 1800 is given for the Alpine glaciers and seven lakes, and for the present century for the Alpine glaciers and 10 lakes in Europe; Caucasian glaciers and 12 lakes in Asia; 10 lakes in N. America; 2 lakes in S. America; 6 lakes in Africa; and 3 lakes in Australia. As a result of a careful study of these data, Brückner finds that there is no law of retardation of epochs (phases) as regards longitude or latitude; but in general the periods of high and low water occur simultaneously over the whole earth. The period from maximum to maximum, or min. to min. oscillates between 30 and 40 years, with an average of 35·6 years. If we are to judge of the climate by these oscillations of lakes without outlet, we obtain the following little table:

Climate Dry or warm or dry and warm.			Climate Wet or cold or wet and cold.		
Before and about	1720	min. water.	Before and about	1740	max. water.
"	1760		"	1780	
"	1800		"	1820	
"	1835		"	1850	
"	1865		"	1880	

A similar table of the times of maxima and minima of water in 13 rivers and 13 river-lakes is as follows:

Minima.	Maxima.
About 1760	About 1740
" 1795	" 1775
" 1831/35	" 1820
" 1861/65	" 1850
	" 1876/80

It is seen that these periods are about the same for all three classes of bodies of water, and a common climatic cause must exist on all continents.

But these are in a measure indirect determinations of the oscillations of those factors which go to make up climate. Direct observations of rain-fall, temperature, etc., have been made for a sufficient length of time to furnish material for closer determination of changes of climate than that just mentioned. We will now summarize these.

Rain-fall.—Brückner has made use of observations at 321 points on the earth's surface, and distributed as follows: Europe 198, Asia 39, North America 50, Central and South America 16, Australia 12, Africa 6. It is seen that most of these are in the northern hemisphere, but only those stations could be used where the observations extended over a suffi-

ciently long period. While for most of the stations the data are for the period 1830–1885, yet for many they extend farther back, at Paris beginning in 1691–95. In dealing with such immense masses of data, it would be too burdensome to use single years, and so the averages for five year periods are used; thus 1691–95 refers to the mean for the years 1691–92–93–94–95. The following table contains the average result of these data since 1830.

PERIODS OF RAIN.

	Deficiency.	Excess.	Deficiency.	Excess.	Deficiency.
Europe	1831–40	1841–55	1856–70	1871–85	
Asia	1831–40	1841–55	1856–70	1871–85	
Australia	–45	1846–55	1856–65	1866–75	1876–85
N. America	1831–40	1841–55	1856–65(71–75)	1866–70(76–85)	
Cent. and S. Amer.	1831–45	1846–60	1861–75	1876–85	
Taken all together	1831–40	1846–55	1861–65	1876–85	

The average amplitude of oscillation expressed in per cent. of the total average amount of rain-fall is as follows: Europe 16 per cent, Asia 30 per cent, Australia 22 per cent, North America 26 per cent, Central and South America 28 per cent; the average for all being 24 per cent. That is in the driest period the rain-fall is only $\frac{3}{4}$ of that in the rainiest. It appears also that this oscillation is true for the whole of the land surface and that a deficiency in one section is not counterbalanced by an excess in another section. What takes place on the water surface of the globe we do not know with certainty, as the rain-fall observations at sea are not suitable for such investigations, but the sea-coast stations probably indicate fairly well the results for the open ocean.

It has been suggested that with a shifting towards the eastward a regular retardation of the time of maximum or minimum exists; but Brückner shows that no such relation exists either with change of longitude or latitude. As regards the amplitude of the oscillation, it can be said that while it does not vary very much for the same place, yet for different regions of the earth's surface it is by no means the same. In fact there is found to be the general law that intensity of the oscillations of rain-fall increases with the continentality of the region. The average ratios of maximum : minimum and the average rain-fall at the maximum and minimum for the period 1830–1880 according to the continental distribution, and also arranged for progressive longitudes are as follows:

	Ratio Max : min.	Average min.	Average max.
East part of England	1·18	599mm	744
North Germany	1·23	573	705
S. W. Russia	1·26	447	570
S. E. Russia	1·40	273	384
Ural Mt. Region	1·36	350	480
W. Siberia	2·31	149	347
E. Siberia	1·59	355	564
Deccan	1·24	---	---
U. S. America, W. Coast	1·38	379	517
" " far western interior	1·42	483	684
" " Southern part	1·36	---	---
" " Eastern interior (Ohio, etc.?)	1·20	890	1059

Thus we see that in West Siberia 2·3 times as much rain falls in the rainy period as in the dry period.

The observations along the east coast of the United States, some of the islands of the Atlantic Ocean, and the Irish coast, show minima at about the time of these maxima at the interior; and if these be taken to represent the Atlantic Ocean rain-fall, then there exists in the case of this ocean a compensatory oscillation of rain-fall, the reverse of the oscillations on the land. We have in reality during long periods, a shifting back and forth of the isohyetal lines (lines of equal rain-fall). The amount of this for various isohyetals is shown in the following table; in the first columns for the period from the minimum of 1861–65 to the maximum of 1881–85, and in the second column for the average maximum and minimum.

Displacement in Kilometers.

Counting + towards inland.

	Old World.		N. America.	
Isohyetals.	West side.	West side.		
1000mm	−1000	−600	200	700
900	− 500	−200	300	500
800	+ 300	100	400	600
700	+1500	1000	500	500
600	+ 400	1600	1200	1100
500	+ 600	1000	2000	2000
400		800	vanishes	vanishes
300	vanishes	vanishes		

It has been pointed out before what an important factor this displacement becomes in investigating questions concerning any actual increase of rain-fall. There have been found periods of rain-fall with the following maxima and minima; the former being given in large type and the latter in small type:

1691–1715	1806–25
1716–35	1826–40
1736–55	1841–55
1756–70	1856–70
1771–80	1871–85
1781–1805	

For the present century more exact dates can be assigned to the times of actual maximum and minimum of rain-fall and they are as follows:

1815	1861–65
1831–35	1876–80
1846–50	

From this it would appear probable that we are about to enter upon another period of very low rainfall about 1890–95.

Atmospheric Pressure.—The study of synoptic charts, and the theoretical studies of Ferrel, Guldberg and Mohn and others, have shown us the controlling influence of the distribution of air pressure on climate for short periods and the desirability of a comparative investigation for long periods was unquestioned; but the data for such a work were in such a condition that the chance was exceedingly slight for obtaining any results deserving of notice. Brückner has boldly attacked the problem, however, and has deduced some conclusions which the agreement of so many different series of observations forbid our criticizing as being based on deviations within the possibility of errors for single or a few places of observation. These investigations are based mainly on the matter presented by Hann in his recent great work on the "Air Pressure in Europe;" and in fact without this work as a basis, Brückner would have been obliged either to forego this investigation or else to spend a year or so in the critical discussion of his preliminary data. As it is, his results refer mainly to Europe, and cannot be made to include other continents until some one has done for the observations of the air pressure on them what Hann spent two years (and many more in preparation) in doing for Europe.

The oscillations of the air pressure are discussed by Brückner under two heads: those of the annual averages and those of the seasons. The table on the following page shows the lustra deviations of the air pressure in millimeters from the average for 1851–1880, and also the rain-fall in per cents.

We see here that for the North Atlantic Ocean a relation exists the reverse of that in Central Europe.

The following arrangement shows the pressure variations in winter and summer for the dry and wet periods:

Relative Pressure.

	North Atlantic.		W. and Central Europe.		E. Europe and N. Asia.	
	Winter.	Summer.	Winter.	Summer.	Winter.	Summer.
Dry period,	Lower.	Higher.	Higher.	Higher.	Higher.	Lower.
Wet period,	Higher.	Lower.	Lower.	Lower.	Lower.	Higher.

The discussion of these oscillations shows that for the dry period as compared with the rainy period there exists: (1) A

deepening of the constant cyclone which the annual means show for the North Atlantic Ocean; (2) an increase of the high pressure which extends from the Azores to the interior of Russia; (3) a deepening of the low pressure in the northern part of the Indian Ocean and China Sea; (4) a decrease of the high pressure which exists, for the yearly means, over Siberia; (5) a general increase of the amplitude of the annual oscillation, which causes in the dry period in winter a relatively high pressure in Europe and Siberia and a relatively low pressure over the North Atlantic Ocean; and in summer a relatively low pressure in Central and Western Europe and on the North Atlantic Ocean.

		1826-30	31-35	36-40	41-45	46-50	51-55	56-50	61-65	66-70	71-75	76-80	81-85
Cent. Europe.	Pressure ...	+·08	·92	·02	−·29	−·19	−·35	·17	·42	−02	·10	−·33	·34
	Rainfall ...	−1	−10	−1	4	1	4	−4	−10	0	0	10	6
N. Atlantic.	Pressure ...				−·08	−·18	·54	·51	−·78	−·12	−·13	·32	−·73
	Rainfall ...				1	2	0	0	3	5	2	−6	−10
W. Siberia.	Pressure ...				−·23	00	−·09	−·04	−·46	−·49	−·08	·09	·24
	Rainfall ...				24	31	1	13	−34	24	14	54	74
E. Siberia.	Pressure ...				--	·45	−·06	−·04	−·10	−·45	·29	·36	·21
	Rainfall ...				26	15	0	−20	−10	−5	9	23	28

Each rainy period is, then, accompanied by a smoothing out of all differences of air pressure, and each dry period by a sharpening of them, not only for annual averages from place to place but also for the seasonal averages at the same place. But it is to the amounts and directions of the gradients of air pressure that we owe the general rain-fall conditions, and it is to these long period oscillations of air pressure that we owe the simultaneous long oscillations of rain-fall. We need, however, a similar comparison for other portions of the globe before these relations can be said to be completely proven to have a general applicability.

Temperature.—The much more intimate temporary relations which exists between air pressure and temperature than be-

tween pressure and rainfall leads us to confidently expect that the long period relations of the former will be more readily recognized than those just found for the latter. For the temperature oscillations Brückner has computed lustra means for many places in 22 extended regions, and he has also made use of Köppen's data for 29 regions. The observations used do not extend much back of the beginning of the present century, except for a very limited number of places, and in nearly all cases they are for the northern hemisphere.

These investigations give the following periods of relative heat and cold:

Köppen.		Brückner.	
Warm	1791–1805	Warm	1791–1805
Cold	1806–1820	Cold	1806–1820
Warm	1821–1835	Warm	1821–1835
Cold	1836–1850	Cold	1836–1850
Warm	1851–1870	Warm	1851–1870
		Cold	1871–1885

Only 5 per cent of the material used by Köppen and 8 per cent of that used by Brückner showed the opposite relation to the ones given; but perhaps 15 per cent gave no definite results the one way or the other. The following table shows the amounts of excess (+) and deficiency (—) of temperature referred to the average temperature as determined by many years of observation.

	1821–25.	1836–40.	1866–70.	1821–25.	1836–40.	1866–70.
Tropics	+·34°	—·37°	(—·10°)	+·20°	—·05°	(—·09°)
Sub-tropics	+·66	—·40	+·10	+·59	—·26	(+·03)
Warm temperate	+·49	—·56	+·21	+·37	—·35	+·16
Cold temperate	+·47	—·33	+·20	+·40	—·17	+·14
Cold zone or sub-Arctic	+·81	—·20	+·37	+·69	—·23	+·19

In the first half of the table are the actual differences of the lustra averages from the mean; and when these maxima and minima are determined by taking into account the values for the lustra on either side, the amounts are somewhat diminished; these are given in the last half of the table. For the average of the whole earth (so far as observed at the various dates) the times and relative amounts of the maxima and minima are:

1736–40	—·43°	1821–25	+·56°
1746–50	+·45	1836–40	—·39
1766–70	—·42	1851–55	+·11
1791–95	+·46	1866–70	+·11
1811–15	—·46	1881–85	—·08

We see, then, that the amount of change in temperature during the 36 years period of oscillation is about 1° C. or nearly

2° Fahrenheit. For Central Europe this would mean a displacement of isotherms by a distance of 3° latitude, or about 200 miles, during the time of oscillation; and this is no inconsiderable climatic change, for it places the temperature of the lowest period at Riga equal to the coldest at Königsberg.

We have next to consider the climatic oscillations as shown for northern Euro-Asia by the duration of time when the waters (rivers) are free from ice, and the dates of their becoming free from ice in the spring; the secular oscillations of the dates of the grape harvest for Central Europe, and the cold winters of which we have records. The following table gives the deviations, at the times of maxima and minima, in days, from the average for 1816–80, of the lustra periods of the days free from ice, the averages being *smoothed out;* the negative sign denoting the colder periods:

1736–40	−9·6	1811–15	−8·6
1766–70	+4·0	1821–25	+4·5
1781–85	−3·6	1836–40	−5·0
1791–95	+0·6	1876–80	+3·0

These data refer to the average of the observations in Euro-Asia and for a short period for the Hudson River.

Brückner gives the corrections in days to reduce the dates of breaking up of the ice to the average for 1816–1880 for the separate regions, but does not seem to have been able to unite them in an average. Rykatschew's great memoir on the opening and closing of the rivers of Russia and Siberia serves as the chief basis of this research on the ice conditions. On the average the difference in the number of days free from ice between the cold periods and the warm periods amounted to about 16 days for Siberia, 18 days for Central Russia, 25 to 32 days for W. and S. W. Russia respectively, and 24 days for the Hudson River. The dates for breaking up of winter ice varied about half these amounts for these Euro-Asiatic regions.

The record of the dates of the time of the grape harvest in France, South Germany and Switzerland extends back for several hundred years, and the material has been used to determine the forwardness and backwardness of the seasons which are to a certain extent representative of the character of the year. The data used by Brückner extend back to the year 1496. There are regular oscillations from early to late harvests and these periods obtained from smoothed out data are given in the following table:

Early harvest.	Late harvest.	Early harvest.	Late harvest.
1501–05	1511–15	1681–85	1696–1700
1521–25	1546–50	1725–30	1741–45
1555–50	1566–70	1756–60	1766–70
1586–90	1591–95	1781–85	1816–20
1601–05	1626–30	1826–30	1851–55
1636–40	1646–50	1866–70	1886–88
1656–60	1671–75		

While for single years the amount of variation in the time of grape harvest may vary by many days, and for the five years lustra reaches even three weeks, yet for the smoothed out lustra averages the extremes are about a week earlier than the average for the minima and a week later for the maxima times of harvest. A comparison of these periods with similar periods of rain-fall and temperature shows that in general the early harvest period is identical with that of high temperature and small rain-fall, and conversely the times of late harvest and low temperature and excessive rain-fall occur together. By means of the recorded dates of the grape harvest it is possible therefore to trace back to about the year 1400 for Central Europe the periods of warmth and dryness, and cold and excessive wetness. The relation to the glacier changes are still closer.

The occurrences of severe winters have been catalogued still further back, and Brückner commences his list (using that of Pilgram) with the year 800, but thinks that the records before the year 1000 are of little value. He finds finally that for the period 1020 to 1190, there exists a 34 years oscillation; from 1190 to 1370, a 36 years period; from 1370 to 1545, a 35 years period; from 1545 to 1715, a 34 years period; and from 1715 to 1890, a 35 years period.

An average time of about 35 years is, then, found to intervene between one period of excess or deficiency of heat and the next, with the opposite relative condition of moisture accompanying; and this shows itself in all of the various data and methods which have been used in considering the question.

Princeton, N. J., Dec. 1890.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *On the Law of Osmotic Pressure.*—Planck, in applying the general conditions of thermodynamic equilibrium to the case of a dilute solution separated from the pure solvent by a membrane which allows only the solvent itself to pass and not the dissolved substance, finds that when equilibrium results, there must exist on the side of the solution a greater hydrostatic pressure than on the side of the solvent. And moreover, that this necessary pressure-difference increases proportionally with the number of dissolved molecules in a unit of volume and with the absolute temperature; the factor of proportionality being the same as for gases. But this is the law of osmotic pressure as originally stated and experimentally established by van't Hoff. So that this law now appears as a direct consequence of the fundamental principles of thermodynamics; and not only the law itself, but also all

the conclusions legitimately drawn from it, may be considered to have the same accuracy as the thermodynamic basis upon which they rest.—*Zeitschr. Physikal. Chem.*, vi, 187, Aug. 1890.

G. F. B.

2. *On an Osmotic Experiment.*—The following osmotic experiment has been suggested by NERNST. If two solutions of benzene in ether are separated by a water-layer, this layer must evidently act as a semi-transmitting partition, for the reason that the ether only is markedly dissolved by the water and can therefore diffuse through it, the benzene not having this power. A diffusion-current must necessarily be set up in consequence, provided the concentration of the two benzene solutions is different. Evidently if the two solutions are isosmotic, the ether will dissolve into the water-layer equally from both sides, according to the law of its solubility, and hence no transferrence of the ether will take place through the separating layer. But if the number of dissolved molecules in the two solutions is different, the solution with less osmotic pressure will have a greater solubility in the water than the other; the direct consequence of which will be a fall of concentration of the ether in the intermediate layer and a consequent diffusion, transferring ether from the more dilute to the more concentrated solution. At the same time, the separating partition will be subjected to an excess of pressure in one direction, which excess is the difference of the osmotic pressures of the two solutions. The author has experimentally verified these conclusions, fixing the water-layer by means of an animal membrane, tied over the mouth of a funnel. With an 8 per cent solution of benzene in ether within the funnel and ether alone upon the outside, a rise of from 5 to 10 cm. in an hour was observed, the flow continuing until the height of the column was over a meter. Nernst believes that osmotic phenomena in plants are accomplished in a similar way by the selective solubility of liquid separating layers. —*Zeitschr. Physikal. Chem.*, vi, 37, Aug. 1890; *Ber. Berl. Chem. Ges.*, xxiii, Ref. 620, Nov. 1890. G. F. B.

3. *On Determinations of Molecular Mass by means of Solid Solutions.*—Raoult's law of the reduction of the freezing point of solutions by dissolved substances has now been satisfactorily established for eighteen different solvents; and in consequence the law of Avogadro must also hold true for these substances. Certain exceptions, however, have been noticed; and VAN'T HOFF supposes these to be due to the fact that the crystals which separate are not the pure solvent but a solid solution of the dissolved substance in the solvent. Examples of solid solutions are isomorphous mixtures, amorphous solutions such as glass, hydrogenized palladium, etc. In these solutions, diffusion goes on as in liquids; double decomposition taking place in solids under pressure, glass acting as an electrolyte, carbon diffusing through iron and porcelain. So that there is osmotic pressure in solids; and if this is kinetic, the laws of gaseous and liquid diffusion will apply here, and the osmotic pressure should be proportional to the concen-

tration. This seems to be the case in the absorption of hydrogen by palladium, the gas being at first absorbed under a constant pressure of 225 mm. until 600 parts by volume have been taken up, producing Pd_2H. After this the amount of hydrogen absorbed is proportional to the pressure. Again analogy with liquid solutions would lead us to expect a reduction in the vapor-pressure of a solid when it takes any other substance into solution; and we find that many isomorphous mixtures are more stable and do not effloresce as readily as their constituents. Moreover, this reduction of the vapor pressure of a solid by the introduction of foreign material is of importance in considering the effect which the separation of a solid solution in place of the pure solvent has on the lowering of the fusing point. For since the freezing point of a solution is the point at which the vapor-pressure of the solution and of the separating solid is the same, the smaller the vapor-pressure of the solid the higher will be the melting or freezing point of the solution. Hence the separation of a solid solution from a solvent in place of the pure solvent, would make the fall in the freezing point too high or would cause too small a depression of the freezing point. This occurs most often in those cases in which we might expect the formation of a solid solution from the union of solvent and dissolved substances as in a solution of metacresol and parabromophenol in phenol, of aldoxime in acetoxime and of thiophene and pyridine in benzene. Evidently if the Raoult methods are applicable to solid solutions, these should be available for determining molecular mass. From the proportionality, for example, between the amount of hydrogen absorbed by palladium and the gas-pressure, it would seem that the conclusion that free hydrogen has the same molecular composition as that held in solution by palladium, is a rational one.—*Zeitschr. Physikal. Chem.*, v, 322; *J. Chem. Soc.*, lviii, 1044, October, 1890.

G. F. B.

4. *On the Properties of Liquid Chlorine.*—KNIETSCH has made an extended investigation upon the physical properties of liquefied chlorine. He finds that from its melting point, given by Olsewski at $-102°$, its pressure increases from 37·5 mm. of mercury at $-88°$ to 560 mm. at $-40°$, its mean expansion-coefficient between these limits being 0·001409. At $-33·6°$, its vapor-pressure is 760 mms.; and this is therefore its boiling point. From this temperature to $-10°$, under a pressure of 2·63 atmospheres, its expansion-coefficient is 0·001793. At 0°, its pressure is 3·66 atmospheres and its coefficient of expansion is 0·001978. At 20°, the pressure is 6·62 atmospheres and its coefficient 0·002190. At 60°, its pressure is 18·6 atmospheres and its coefficient 0·003460. At 100°, its pressure is 41·7 atmospheres and at 146°, its critical temperature, it is 93·5 atmospheres.—*Lieb. Ann.*, cclix, 100; *Ber. Berl. Chem. Ges.*, xxxii, Ref. 629, November, 1890. G. F. B.

5. *On the Preparation of Chromium by means of Magnesium.*—GLÄTZEL has experimented successfully to obtain metallic chromium by reduction with magnesium, using for the purpose

the double chloride of chromium and potassium. This double chloride was prepared by reducing potassium dichromate with alcohol and hydrogen chloride, adding the necessary additional quantity of potassium chloride, filtering, evaporating to dryness and heating the mass until dehydrated. Double the necessary amount of magnesium, in the form of filings, was then added to the pulverized mass, that is 50 grams of filings to 260 of the double chloride, and the whole was placed in a Hessian crucible, covered and exposed to a high temperature in a wind-furnace. After cooling the mass was treated first with water to remove the potassium and the magnesium chlorides, and then after decantation, with dilute nitric acid to remove the excess of magnesium. The chromium which remained undissolved weighed after drying on the water bath 27 grams. It could not be collected on a filter, since it was so finely divided as to run through. It was a bright gray powder appearing as white or yellowish-white crystals under the microscope, having a metallic luster. Rubbed in an agate mortar it gave a streak resembling lead. At 16°, its relative mass was 6·7284. A powerful steel magnet was without action on it. It fused only in a Deville's blast-furnace, giving a mass having a silver-white fracture. Analysis showed it to contain 99·57 per cent chromium.—*Ber. Berl. Chem. Ges.*, **xxiii**, 3127, November, 1890. G. F. B.

6. *On the Production of Urea from Albumin.*—The attempts which have been made to obtain urea by the oxidation of albumin, have given no positive result. DRECHSEL now shows that when casein is boiled with concentrated hydrochloric acid and stannous chloride, a base is produced having the formula $C_6H_{11}N_3O$, and which he calls lysatine. This on boiling with baryta water, affords urea. Hence he regards the lysatine and of course the urea from it, as due not to an oxidation but to a hydrolysation of the albuminate.—*Ber. Berl. Chem. Ges.*, **xxiii**, 3096, October, 1890. G. F. B.

7. *On Azoimide or Hydrazoic acid.*—A remarkable compound of nitrogen and hydrogen N_3H has been discovered by CURTIUS, which bears a striking analogy to the haloid acids and is theoretically formed by the action of nitrous acid upon diamide, as nitrogen is by its action upon ammonia. In the latter case the reaction is

$$NH_4Cl+NaNO_2=N_2+(H_2O)_2+NaCl$$

while in the case of diamide it is

$$N_2H_4HCl+NaNO_2=N_3H+(H_2O)_2+NaCl.$$

In fact, however, the production of the new substance is much less direct. By the action of diamide hydrate upon benzoylglycollic ether, or upon hippuric ether, benzoyl diamide or hippuryl diamide is produced. By the action of sodium nitrite upon benzoyl diamide, benzoyl azoimide is obtained; and this on boiling with sodium hydrate gives sodium azoimide,

$$C_6H_5CO\,N\begin{matrix}\diagup N\\ \parallel\\ \diagdown N\end{matrix} + (NaOH)_2 = C_6H_5COO\,Na + NaN\begin{matrix}\diagup N\\ \parallel\\ \diagdown N.\end{matrix}$$

By the action of an acid upon this, hydrogen azoimide $HN\begin{matrix}\diagup N\\ \parallel\\ \diagdown N\end{matrix}$ or hydrazoic acid (stickstoff-wasserstoffsäure) results. The action of sodium nitrite upon hippuryl diamide gives nitroso-hippuryl diamide; and this on boiling with acids or alkalies gives hippuric and hydrazoic acids. The new substance hydrazoic acid, is a gas having a peculiar and intensely pungent odor, producing even when dilute, pain in the head and dizziness, and causing inflammation of the mucous membrane of the air passages. In aqueous solution it corrodes the skin. It is a strong monobasic acid recalling closely hydrochloric acid. It is readily soluble in water; and on heating the solution, gas at first escapes and then a concentrated aqueous acid distills over between 90° and 100°, containing 27 per cent of HN_3. This aqueous acid has the odor of the gas, reddens litmus paper strongly and produces white fumes with ammonia. A seven per cent solution dissolves iron, zinc, copper, aluminum and magnesium with active evolution of hydrogen; and the concentrated acid appears even to attack gold and silver, since it is colored red in contact with these metals. Silver nitrate and mercurous nitrate give precipitates of silver and mercurous nitride, AgN_3 and $Hg_2(N_3)_2$. Both the acid and its salts are fearfully explosive; two c. c. of a 27 per cent acid detonated with great force while being sealed and blew the tube to dust.—*Ber. Berl. Chem. Ges.*, xxiii, 3023, Oct., 1890.

G. F. B.

8. *New Method of obtaining the Compressibility and Dilatation of Gases.*—E. H. AMAGAT describes an apparatus by means of which he has been able to study this subject up to the temperature of 200° C. and to a superior limit of pressure equal to 100 atmospheres. Results are given for oxygen, hydrogen, ozone and air. The coefficient of dilatation for hydrogen diminishes regularly when the pressure increases. For ozone, oxygen and air, it passes through a maximum which, at the limit, corresponds to the pressure for which the pressure multiplied by the volume is a minimum.

For hydrogen the values of $\frac{dp}{dt}$ are sensibly independent of the temperature. Air and ozone approximate to the behavior of hydrogen. This latter gas appears to attain a limiting state, towards which the other gases converge when the temperature rises. Forms of the isothermals are referred to in this paper.—*Comptes Rendus*, p. 871, Dec. 8, 1890. J. T.

9. *Mechanical equivalent of heat by method of heat radiation.*—J. SAHULKA has modified the ordinary lecture-room apparatus by means of which the heat developed by friction is shown, so that it can afford quantitative results. A revolving

hollow iron vessel is provided with another vessel closely fitting it. The latter constitutes a Prony friction brake. It is properly mounted with a scale pan at the end of a lever. The revolving vessel is filled with mercury and the friction of the inner iron vessel of the Prony brake against the revolving vessel raises the temperature of the mercury. The temperature of the mercury is raised to 30° higher than that of the room, and the rotation of the apparatus is so regulated as to maintain this heat constant. Thus the generation of heat is equal to the radiation into the room; a simple calculation gives as a value of the mechanical equivalent, $J = 426, 262$ mkg. with a mean error of each determination of $\pm 2{\cdot}479$. The apparatus is well calculated by its simplicity to take the place of the old form of demonstration apparatus.—*Ann. der Physik,* Nov. 12, 1890, pp. 748–755.

J. T.

10. *Electrical waves in open circuit.*—A. ELSAS employes one Daniell cell, and hangs a telephone upon a continuation of a wire connected with one of the poles of this cell. The connection between the poles of the battery is broken close to these poles by a peculiar current breaker. The telephone at the end of the wire gives a tone which depends upon the self-induction and capacity of the wire upon which it is hung. Various modifications of this experiment are described. The telephone is employed in place of a Hertz resonator, to show waves on the wire of the open circuit.—*Ann. der Physik,* Nov. 12, 1890, pp. 833–849. J. T.

11. *Electrical Waves.*—H. ERNST LECHER describes a new method of studying Hertz's phenomena. Instead of a resonator of the type employed by the latter, a Geissler tube is used. Two parallel wires of known self-induction terminate at one end in condenser plates, which are charged in an oscillatory manner by a large Ruhmkorf coil excited by storage cells. Upon the other ends of the parallel wires rests the Geissler tube. A short wire is then slid along the parallel wires connecting them across like a bridge between two parallel wires on a sonometer. At certain definite points the Geissler tube glows, and the wave lengths of the electrical oscillations can thus be measured. Lecher finds that the velocity of electricity in metallic wires is that of the velocity of light. He points out a slight inaccuracy in Hertz's work.—*Ann. der Physik,* Nov. 12, 1890, pp. 850–870.

J. T.

12. *Electrical Gyroscope designed for rectification of the mariner's Compass.*—A small electrical motor sets in action a gyroscope; advantage is taken of the invariability of the plane of rotation at definite positions in latitude and longitude, to correct for the deviation of the mariner's compass. The instrument is provided with a small astronomical telescope for observations on the stars. The apparatus is the invention of M. G. Trouvé.—*Comptes Rendus,* p. 913, Dec. 15, 1890. J. T.

13. *On the periodicity of the Aurora;* by M. A. VEEDER (communicated).—If the numbers of stations reporting auroras daily

in the Monthly Weather Review, or any similar publication, are arranged in periods of twenty-seven days, six hours, and forty minutes, so that corresponding days of the successive periods fall in the same vertical columns, it will be found that the larger numbers showing increased prevalence of the aurora are grouped together as a rule, indicating the existence of a periodicity at this interval, which corresponds to the most generally accepted value for a synodic revolution of the sun. The succession of larger numbers in the same vertical columns is generally interrupted near full moon, seemingly because of moonlight, so that the track of the moon can be traced, extending diagonally across tables constructed in this way. Aside from these breaks the periodicity is at times clearly apparent for years in succession. The six hours, or one-quarter day, may be provided for by adding a day to each fourth period, and the forty minutes or one thirty-sixth of a day by adding a day to each thirty-sixth period.

Lyons, N. Y., Jan. 16, 1891.

II. Geology and Mineralogy.

1. *Ninth Annual Report of the United States Geological Survey to the Secretary of the Interior*, 1887–'88, by J. W. Powell, Director. Washington, 1889. The opening pages (1–44) of this volume give the Report of the Director, indicating the progress made during the year in the various departments; this is followed (49–154) by administrative reports by the heads of divisions. The bulk of the volume is given to four long and valuable papers: (1) pp. 209–528 by Capt. Dutton on the Charleston Earthquake of Aug. 31, 1886; (2) pp. 537–610 by Prof. Shaler on the geology of Cape Ann, Mass.; (3) pp. 619–676 by W. H. Weed, on the formation of travertine and siliceous sinter by the vegetation of hot springs (specially noticed below); (4) by Dr. C. A. White on the geology and physiography of a portion of northwestern Colorado and adjacent parts of Utah and Wyoming. The discussion of the Charleston earthquake by Capt. Dutton is exhaustive and able, and the results of much value. The earthquake is remarkable as one of great severity, taking place independently of any region of volcanic activity. The conditions existiug for obtaining a full record, over the country involved, of the time, duration and effects of the earthquake were on the whole unusually favorable, and the energetic action of several gentlemen connected with Survey, aided by Mr. Earle Sloan and others of Charleston, has resulted in the accumulation of a large amount of material, embracing no loss than 4,000 reports from 1,600 localities. The detailed descriptions of the phenomena observed are supplemented by independent and graphic accounts by three observers in Charleston, Messrs. McKinley and Fisher, and Dr. Manigault. A large number of full page illustrations from photographs give a striking impression of the damage done.

The chief scientific result from the study of the earthquake, as has indeed been already discussed in this Journal (vol. xxxv, 1, 1888), is the conclusion as to the speed of propagation of the earthquake-wave, the result being $3{\cdot}226 \pm 0{\cdot}147$ miles, or 5192 ± 236 meters per second. This velocity is not only entitled to much greater weight than results obtained in connection with similar phenomena elsewhere, but, further, it agrees closely with the calculated rate of propagation of a wave in an elastic, nearly homogeneous, solid medium of materials corresponding to those here involved. Capt. Dutton's chapter upon the nature and mechanism of wave motion is an excellent summary of the subject. As exhibited on plate xxvi, there were found to be two epicentral regions near Charleston, one 15 miles northwest near Woodstock, about which the isoseismals are nearly circular; the other to the south of this and 12 miles west of Charleston, on Rantowles Creek, with oval isoseismals, the major axis extending toward Woodstock. At the former center, the deduced depth of the focus is 12 miles, with a probable error of 2 miles; at the other the material for conclusion was less satisfactory, but the depth is made about 8 miles. Plate xxix gives the isoseismals over the whole country, extending from the Atlantic border to a little west of the Mississippi and north through the center of the Great Lakes. No definite conclusion is reached in regard to the nature of the forces which caused the disturbance.

2. *Formation of Travertine and siliceous Sinter by the Vegetation of Hot Springs;* by WALTER HARVEY WEED.—This monograph accompanies the Ninth Annual Report of the U. S. Geological Survey (pp. 613–676), and has also been issued separately. The abundant growth of algæ in hot springs has been noticed by many observers, but it has usually been heretofore regarded as an interesting biological fact rather than a matter of any considerable chemical or geological significance. It is well known that some water plants abstract carbonate of lime from its solutions, and Cohn has shown that the growth of vegetation is a factor in the production of travertine at Carlsbad. Beginning with a study of the deposits about the hot springs in Yellowstone Park, Mr. Weed shows that plant life is an important factor in the deposition of the travertines, tufas and sinters from calcareous waters, and that some of the more striking physical appearances of these deposits are due to algæ. Of even more chemical and geological interest is the connection he shows between the deposition of siliceous sinter from alkaline hot waters and plant growth. Algæ in great abundance and of varied and often brilliant colors are found on and in the forming sinter about the hot springs in various parts of the world. Such deposits are especially extensive in Yellowstone Park, covering many square miles. Heretofore, the separation of silica from hot solution about geysers and hot springs has been supposed to be due to purely chemical and physical causes, to relief from pressure, cooling, evaporation, and chemical reaction. Mr. Weed shows, that much of the silica

(and what proportion it is impossible to determine) is eliminated from solution by the vital action of algæ, and that algæ are an essential factor in producing many of the varied and beautiful forms of the deposits in the Park. The fretted rims of the pools, the coral-like and mushroom-like deposits, the "marble terraces" and "petrified waterfalls" owe their physical characters, in part, at least, to vegetable growth. The evidence seems conclusive, and the author reviews the literature relating to hot springs in various parts of the world, and deduces the inference that much of the deposits about them, both calcareous or siliceous, are produced in the same way. The writer of this note has seen several cases of both kinds of deposition, in each case accompanied with algous growth, then considered an effect rather than a cause. The most considerable was at the Steamboat Springs in Nevada, where, upon the enormous mass of growing sinter there was an abundant growth of minute algæ of various and often brilliant colors, flourishing luxuriantly in the warm gelatinous silica, the effect made the more striking by a fierce snow storm which was raging. Mr. Weed's conclusions are that plant-life is a very wide spread and important agent in the production of travertine, tufas and sinters. This is the more interesting, because within a few years researches on the chemical functions of other low vegetable organisms have shown that natural changes formerly supposed to be due to purely chemical action are in reality dependent on vital or physiological action in some way. Vitrification in soils, the decomposition of sulphates in brackish waters are illustrations, and Mr. Weed's observation extends our knowledge of the part that vital action plays as a geological agent. W. H. B.

3. *Geological Survey of Illinois*, A. H. WORTHEN, Director. Vol. viii. *Geology and Paleontology.* 728 pp., 8vo, with an Appendix of 152 additional pages. Illustrated by a portrait of the distinguished head of the Survey (who died in May, 1888), and a small geological map of the State; and also, under separate covers, 78 lithographic plates of fossils. Edited by J. Lindahl, Ph.D., State Geologist.—This volume completes the very valuable series of reports of the Geological Survey of Illinois. The series is second, among the State Geological reports of the country, in the extent of its paleontological contributions, and first, in the part of the paleontology relating to the Carboniferous limestones. It contains, after an introduction by Mr. Lindahl, chapters on the following subjects—(1) the Drift of Illinois, its Coal, Natural Gas and Oil, and some fossil Invertebrates, by A. H. WORTHEN, papers that were left unpublished by their author; (2) new species of Crinoids and Blastoids from the Kinderhook group of the Lower Carboniferous rocks at Le Grand, Iowa, and a new genus from the Niagara group of Western Tennessee, by CHARLES WACHSMUTH and FRANK SPRINGER; (3) American Paleozoic Sponges, Sponges of the Devonian and Carboniferous systems, and Paleozoic Bryozoa, by C. E. ULRICH; (4) Descriptions of Lower Silurian Sponges, by E. O. ULRICH and OLIVER

EVERETT. The Appendix consists of a memoir of Prof. Worthen, by N. W. Bliss and C. A. White, with the portrait mentioned above, and a general Index to the whole series of eight volumes, which covers 112 pages. The excellent plates of fossils are largely from drawings by Charles K. Worthen, son of the director.

4. *The Geological Society of America* held its second annual meeting on Dec. 29th, 30th and 31st. There were almost 70 Fellows present, including representatives from Canada, New Mexico, Texas, Dakota and nearly all of the intermediate States. Fifty-two papers were placed on the programme and forty of them were read. The Society worked very hard, sessions being held in the evenings of the 29th and 30th.

The condition of the Society is very satisfactory; there are now 202 Fellows on the roll; the first volume of the Bulletin, published last year, contains 605 pages with 13 plates and 51 maps and figures. The permanent fund already amounts to 2,000 dollars and the Society has in hand rather more than 1,000 dollars with which to begin the work of the new year. The Society has given good proof of necessity for its existence, not only by affording an opportunity for publication of memoirs but especially by bringing geologists together and enabling them to present views to each other in person. Already many misunderstandings have been changed into understandings; and the excellent results of the meetings are binding geologists together.

The new officers are *President*, Alex. Winchell; *Vice-Presidents*, G. K. Gilbert and T. C. Chamberlin; *Secretary*, H. L. Fairchild; *Treasurer*, H. S. Williams; *Councillors*, G. M. Dawson, J. C. Branner, C. H. Hitchcock, E. W. Claypole, I. C. White, J. J. Stevenson; *Editor*, W J McGee.

5. *Geology of the Marquette Iron Region: A Correction by* T. B. BROOKS (communicated).—In my Survey of the Marquette Iron Region (*Geology of Michigan*, 1873, vol. i, p. 130) I state: "Near the center of U. S. linear survey, Section 25, at the west end of Lake Michigamme, is a large mass, *probably* a ledge, of light gray quartzite, which may fill, in part at least, what appears to be a blank between the anthophyllitic schist constituting bed XVII and the mica schist (containing garnets, andalusite and staurolite) constituting bed XIX just described. The number XVIII is *provisionally* attached to this quartzite."

Want of time and means prevented further investigation during the survey. Last summer I found this quartzite (now in open fields instead of dense forest) to be *boulders* and probably drift. Although my stratigraphical work has been ignored by one and severely criticized by another geologist, who have since then worked in this part of the Lake Superior region, I believe that it will in the main stand and may yet prove a piece of fairly good work for its time, especially as my work was purely economic and industrial in its aim. This is a mass of metamorphosed crystalline strata so twisted, broken and faulted as to have been very difficult to make out in the then condition of the country.

Munich, Germany, Dec. 17, 1890.

6. *On Harmotome from the vicinity of Port Arthur, Ontario;* by W. F. Ferrier, (communicated by permission of the Director of the Geol. Survey of Canada).—The specimen of harmotome to be described was obtained in 1887 by Dr. A. C. Lawson, in the Thunder Bay District, Lake Superior. In the absence of Dr. Lawson, the precise locality is not known at present, but it came from one of the mines in the immediate vicinity of Rabbit Mountain (about 22 miles west-south-west of Port Arthur), and, probably from the Rabbit Mountain Mine. The crystallized minerals here fill vugs in true fissure veins which cut the black argillites of the Animikie. On joining this Department it devolved upon the writer to look over the specimens collected by Dr. Lawson and it was in so doing that this specimen was found. The form of the crystals first attracted attention and qualitative tests proved that barium was present in considerable quantity; a further blow-pipe examination proved that the mineral was harmotome.

The crystals are double twins in which each individual is twinned parallel to the base, and these two simple twins again united in a double penetration-twin or fourling, with the clinodome as the twinning plane. These fourlings belong, as shown by the striæ on the crystal faces, to Streng's first type* in which the simple twins are shortened in the direction of the vertical axis. They are for the most part implanted on regular prisms of calcite, terminated by the rhombohedron $-\frac{1}{2}R$, some of which measure 4cm. in the direction of the vertical axis, and 8mm. in that of the horizontal axis. The largest harmotome twin crystal on the specimen was 4mm. long and 1mm. in width. The crystals are white, and vary from subtransparent to translucent. The faces are rough, but some of them show the characteristic striations with much perfection.

Drusy quartz with an amethystine tinge of color forms the base on which the calcite crystals are implanted, and purple fluorite is also intimately associated with these minerals. Pyrite, in aggregations and isolated cubes and octahedrons, is sprinkled over the other minerals, and there is also present another sulphide, in minute tufts of acicular crystals, which may be millerite, but the material available was not sufficient for a satisfactory determination. The only other localities for harmotome in North America which have come under the writer's notice are those of Sing Sing in New York State, and the upper end of New York Island, where it was found in seams in the gneiss at the excavations for the 4th Avenue tunnel,† 1875.

7. *Long Island Sound in the Quaternary Era;* by J. D. Dana. *Erratum.*—In the number of this Journal for December, 1890, page 436, line 22 from top, for eastward read *westward*, and line 24 from top, for westward read *eastward*.

Geol. Survey of Canada, Ottawa, Dec. 27th 1890.

*See "Elemente der Mineralogie," Naumann-Zirkel, 12th Ed., p. 717, fig. 2.
†See "Text Book of Mineralogy," E. S. Dana, pp. 346, 482, 1883.

III. Botany.

1. *Neue Untersuchungen über den Blüthenanschluss;* by Karl Schumann. Leipzig, 1890. (Wm. Engelmann).—In no department of botanical research are methods changing more rapidly than in morphology. While classification, anatomy, and physiology have made, in the last twenty years, unprecedented progress, the advance has been in most instances the result of the gradual extension and perfection of methods previously employed. In morphology on the other hand, not only have the methods been thoroughly revised, but the point of view, from which the entire subject is regarded, has been radically altered. This change is due not merely to an increasing preference for ontogenetic proofs over the much more vague arguments from phylogeny, but especially to a thorough realization that accurate knowledge can only be obtained by observing facts as they are, before attempting to force them into preconceived categories—a general truth, which, however self-evident, has until recently been sadly disregarded in the realm of vegetable morphology. In its vigorous attempt to avoid the defective methods of the past, Dr. Schumann's carefully prepared work merits high commendation. Its subject, the morphological relation of the flower to the neighboring vegetative parts of the plant, may at first seem technical, and of narrow scope for a treatment so extended (520 pages). But the satisfactory solution of the questions to be considered requires an accurate knowledge of both floral and vegetative members of plants, and involves a critical review of the most important parts of morphology.

Although Eichler, Schwendener, Goebel, and others have given much attention to the morphological attachment of the flower, and have examined a great number of particular cases, Dr. Schumann's work is the first exhaustive treatment of the subject, and will without doubt become a recognized standard in this department of morphology. In the opening pages of his book he considers the previous investigations of his subject and gives a number of clear and reasonable criticisms upon the more important theories; then follow the results of his own investigations, which have been confined to the angiosperms. The plants treated are conveniently grouped according to certain morphological similarities, rather than their systematic affinities. Among the monocotyledons, the grasses and sedges receive the most attention; among the dicotyledons, the treatment of the *Rubiaceæ* is perhaps especially full. In the closing pages of the work the results derived from particular cases are collected and thrown into a more general form. Even the briefest summary of these results would exceed the limits of the present review; suffice it to say in general, that they confirm and elaborate the theory of Schwendener, that purely mechanical influences outweigh all others in determining the early development of plant-members, whether foliar, floral, or axial. The work is excellently illus-

trated by 10 plates, containing together 250 figures, chiefly of very early stages in the development of flowers and floral axes. It is worthy of mention that Dr. Schumann in his capacity of Curator of the Botanical Museum of Berlin has had unlimited access to the excellent botanic garden of that city, and has thus been enabled to examine much rare material, never before investigated from the present point of view. B. L. R.

2. *Plantæ Europeæ, Enumeratio systematica et synonymica plantarum phanerogamicarum in Europa sponte crescentium vel mere inquilinarum;* by Dr. K. Richter. Leipzig, 1890. (Wm. Engelmann).—Volume I of this complete index of European flowering plants forms an octavo of nearly 400 pages, and includes the gymnosperms and monocotyledons. In the arrangement of the orders and genera, it follows, without exception, Engler and Prantl's *Natürliche Pflanzenfamilien;* while the species are systematically arranged according to the best monographs. It scarcely need be said, that the only satisfactory test of such an index is long and frequent reference to it, in connection with systematic botanical work. In this way only does its accuracy or defects become apparent. So far, however, as it is possible to judge, Dr. Richter's work is in every way excellent. It certainly possesses many features, which will render it a most convenient work of reference not only for European botanists, but in botanical institutions, especially the larger herbaria, in all parts of the world. The value of the index is much increased by the fact, that the species within the genera are arranged according to their natural affinities, the subgenera being briefly indicated. To obviate any inconvenience from this arrangement an alphabetic list of all the species is appended at the close of the volume. The synonymy is given with much detail, the date and place of publication accompanying every name. The habitat of each species and variety is also indicated, and a full list of known hybrids is given at the end of each genus in which they occur. B. L. R.

3. *Notes on Corticium Oakesii, B. & C. and Michenera Artocreas, B. & C.;* by George James Peirce. (Bull. of Torr. Bot. Club, vol. xvii, No. 12, Dec. 1890).—In a paper of ten pages Mr. Peirce describes the noteworthy peculiarities in the life-history of the two fungi above named. His very interesting observations upon the *Corticium* show that the basidia arise by a late modification in the development of some of the much-branched structures, which are called paraphyses. At other stages in the development of the fungus, some of these so-called paraphyses bear abundant conidial spores. The simple but more or less moniliform threads, which are occasionally found rising from the hymenium among the branched structures, are designated as the "true paraphyses." It is to be regretted that the statement of these facts lacks a certain clearness, which it might have possessed, if Mr. Peirce had defined at the outset the par-

ticular application of his terms, and avoided a double use of the word "paraphysis." The observations too, would seem to warrant rather more wide-reaching conclusions than those drawn, since they have a very important bearing upon the whole question of apogamy among the *Basidiomycetes.* As a result of his study of the rare *Michenera Artocreas*, Mr. Peirce concludes that the flask-shaped spore-bearing cells are a normal form of fruit of this species, and not, as has been thought, the fruit of a parasite. Furthermore, although *M. Artocreas* is not infrequently accompanied by a *Corticium*-like fungus bearing basiospores, the latter have in no instance been observed upon mycelia clearly identified with the *Michenera*. The article closes with some details of methods found useful in the investigation. B. L. R.

4. *Recherches sur l'origine morphologique du liber interne;* by Professor M. LAMOUNETTE. (Ann. des Sciences nat. bot. VII, xl, pp. 193–282, t. 11–13.)—The occurrence among the dicotyledons of anomalous bast in the pith has in recent years been demonstrated in a large number of plants of widely different systematic position, and the development, morphological relations, and physiological significance of this remarkable tissue have proved exceedingly inviting themes for investigation. As a result a considerable literature upon this subject has sprung up, and in the case of the morphological origin of the tissue in question, the views expressed have been widely diverse. A brief résumé of the chief opinions held may here be given, as it will better show the precise bearing of Professor Lamounette's researches.

From the accuracy with which these internal strands of bast follow the primary fibro-vascular bundles, and the structural identity which exists between the anomalous and normal bast, de Bary regarded the former tissue as belonging to the bundles in the same sense as the wood and normal bast, and applied the term "bicollateral" to this peculiar form of bundle. Petersen subsequently examined a great number of plants with internal bast, confirming the opinion of de Bary, and arriving at the conclusion that this tissue arises, in common with the other parts of the bicollateral bundles, from the procambium. Herail, however, observed the significant fact that the internal bast develops in most if not all cases distinctly after the normally oriented tissues of the bundle. He infers therefore that it cannot be morphologically equivalent to the outer bast, and discards on this account the term bicollateral bundle, except as applied in the single group of the *Cucurbitaceæ*, where, in his opinion, the correspondence between external and internal bast is much more complete than elsewhere. Dr. J. E. Weiss approaches the subject from a very different standpoint, in an attempt to prove that the anomalous strands of bast are nothing less than branches of the leaf-trace bundles, which enter the pith at the nodes. The paper* elabor-

* Weiss, Das markständige Gefässbündelsystem einiger Dikotyledonen in seiner Beziehung zu den Blattspuren. Cassel, 1883.

ating this novel theory, although inaccurate in some minor details, is of much interest, since it shows the intimate connection, existing between the bast of the leaves and the anomalous bast of the mature stem; but it by no means solves the question whether the bast of the pith is developed from the original procambium, or by the metamorphosis of some of the medullary cells. Very similar in this respect is R. Gérard's article* on the changes of the tissues at the junction of the root and stem, in which he discusses several plants with internal bast, and finds that small bundles of sieve-tubes connect the anomalous and normal bast just where the root passes into the stem.

In the work before us Professor Lamounette confirms in the main the results of Herail, but goes one step further, since he finds that even among the *Cucurbitaceæ* the internal bast clearly develops later than the external. Not only is this the case at the apex of the stem, and in the formation of the leaf-trace bundles, but also in the first appearance of the anomalous tissue in the hypocotyledonary axis. From this it appears that the so-called bicollateral bundles of the *Cucurbitaceæ* are no more uniform in their development than similar structures in other groups, and de Bary's name for them is no more applicable here than elsewhere. This is but one of the results contained in Professor Lamounette's article, since he has extended his researches to a large number of orders and has devoted special attention to the very early stages in the development of the tissue in question. His observations lead him to place the limit of the tissues derived from the procambium, just within the innermost of the primitive tracheal elements, which would show that the anomalous bast must arise from the division and specialized development of cells which belong morphologically to the pith. This having been settled, it still remains important to ascertain whether the anomalous tissue stands in a primitive connection with the normally oriented bast i. e. whether it is, so to speak, merely a branch of the outer phloem system. Considering the nature of sieve-tubes as conductive tissue, this would a priori appear highly probable. Professor Lamounette, however, has made the surprising discovery that the internal bast, at the time of its first appearance, is entirely separate from the normal system. This certainly seems opposed to the views of Gérard, but the difference in results is probably due to the fact that the latter observer examined somewhat later stages in the development, where a connection between the outer and inner bast had already been formed. In the mature plant there can, of course, be no doubt that these tissues stand in more or less intimate communication, a fact demonstrated in very different ways by Fischer, Weiss, Gérard, and others. While Professor Lamounette's results are without doubt accurate for the plants investigated by him, there is certainly one instance in

* Ann. des sci. nat., 6th series, vol. xi, 1881.

literature,* in which anomalous internal bast arises in a very different way, being developed entirely secondarily, through the activity of a cambium, gradually extending itself inward at the nodes, and entering the pith through the gaps in the fibro-vascular ring, which are left by the outgoing leaf-trace bundles.

B. L. R.

5. *Die Gattung Phyllostylon und ihre Beziehungen zu Samaroceltis.* (Oestr. bot. Zeitschr., Dec., 1890.)—Dr. P. FAUBERT, the author of this short article, having been fortunate enough to obtain fruiting specimens of *Phyllostylon Brasiliense* Capan, finds that they correspond closely to plants upon which the new genus *Samaroceltis* has recently been founded. The conclusion is naturally drawn that the two genera must be united under the older name *Phyllostylon.* While studying these plants Drs. Taubert and Urban have discovered a Cuban form of *Phyllostylon* almost identical with a Paraguay species. This is an additional point in proving a relationship, which seems to exist between the flora of the West Indies and the southern United States on the one hand, and of Paraguay and the Argentine Republic on the other, a peculiarity of botanical geography for which no adequate explanation has as yet been offered. B. L. R.

6. *Eine Notiz über das Verhalten der Chlorophyllbänder in den Zygoten der Spirogyraarten;* by VINCENT CHMIELEVSKY. (Bot. Zeit. 1890, viii, pp. 773–780).—Owing perhaps to the greater importance ascribed to the cell-nucleus, the conduct of the chloroplaslids, during reproduction among the *Conjugatæ*, seems until now to have received but little attention. It has long been supposed that the chlorophyll-bodies of the two conjugating cells in some way unite, both contributing to the substance of the new chloroplastid of the zygospore. In the interesting paper just named, the author shows that this idea is altogether unfounded. In the species of *Spirogyra* studied by him, the chloroplastid of the zygospore develops directly from that of the conjugating cell within which the spore is formed (female .cell), while the chlorophyll of the other conjugating cell takes no part in this process, but gradually loses its color, disintegrates, and after remaining sometime in the spore as a minute mass of brownish pigment, finally disappears altogether. These facts add, as the author concludes, a striking argument for the theory that hereditary traits are transmitted entirely by the agency of the nuclei, the vegetative parts of the cells being, in this regard, entirely neutral. B. L. R.

* Cf. Annales du Jard. bot. de Buitenzorg, vol. viii, pp. 102–111.

Index to Volumes XXXI–XL.

An EXTRA NUMBER giving a full index to volumes XXXI–XL, and forming pp. 505–548 of volume XL, was issued in January. Sent only to those who specially order it—price seventy-five cents.

APPENDIX.

Art. XIX.—*The gigantic Ceratopsidæ, or horned Dinosaurs, of North America;** by O. C. Marsh. (With Plates I–X.)

Two years ago, at the Bath meeting of the Association, I had the honor to present to this section a paper in which I compared the principal known Dinosaurs of Europe with those of America.† In this communication, I referred to some peculiar reptilian remains from the Gosau formation of Austria, and compared them with certain Laramie fossils from America, about which I hoped soon to have more definite information. As an indication of the rapidity with which knowledge of ancient life is advancing, it may interest you to know what has been learned, in two years, concerning this single group of the remarkable reptiles known as *Dinosauria*. This group, I have termed the *Ceratopsidæ*, and I shall speak especially of the forms I have recently investigated, and hope to describe more fully later, under the auspices of the United States Geological Survey.

The geological horizon of the *Ceratopsidæ*, in America, is a distinct one in the upper Cretaceous, and has now been traced nearly eight hundred miles along the eastern flank of the Rocky Mountains. It is marked almost everywhere by remains of these reptiles, and hence I have called the strata containing them, the Ceratops beds. They are fresh-water or brackish deposits, which form a part of the so-called Laramie, but are below the uppermost beds referred to that group.

* Read before Section C of the British Association for the Advancement of Science, at the Leeds meeting, September 4, 1890. See also this Journal (3), vol. xxxvi, p. 477, December, 1888; vol. xxxvii, p. 334, April, 1889; vol. xxxviii, p. 173, August, 1889, p. 501, December, 1889; and vol. xxxix, p. 81, January, 1890, p. 418, May, 1890.

† Report of the British Association for the Advancement of Science for 1888, p. 660. London, 1889. Abstract, this Journal (3), vol. xxxvii, p. 323, April, 1889.

The fossils associated with the *Ceratopsidæ* are mainly Dinosaurs, representing two or three orders, and several families. Plesiosaurs, crocodiles and turtles of Cretaceous types, and many smaller reptiles, have left their remains in the same deposits. Numerous small mammals, also of ancient types, a few birds, and many fishes, are likewise entombed in this formation. Invertebrate fossils and plants are not uncommon in the same horizon.

The Skull.

The skull of *Triceratops*, the best known genus of the family, has many remarkable features. First of all, its size, in the largest individuals, exceeds that of any land animal hitherto discovered, living or extinct, and is only surpassed by that of some of the Cetaceans. The skull represented natural size in two of the diagrams was that of a comparatively young animal, but is about six feet in length. The type specimen of *Triceratops horridus* was an old individual, and the head, when complete, must have been seven or eight feet in length. Two other skulls, nearly perfect, represented by life-size sketches, and several others from the same horizon, have almost equal dimensions.*

Another striking feature of the skull is its armature. This consisted of a sharp, cutting beak in front: a strong horn on the nose; a pair of very large, pointed horns on the top of the head: and a row of sharp projections around the margin of the posterior crest. All these had a horny covering of great strength and power. For offense and defense, they formed together an armor for the head as complete as any known. This armature dominated the skull, and in a great measure, determined its form and structure. In some forms, the armature extended over portions of the body.

The skull itself is wedge-shaped in form, especially when seen from above. The facial portion is very narrow, and much prolonged in front. In the frontal region, the skull is massive and greatly strengthened to support the large and lofty horn-cores which formed the central feature of the armature. The huge, expanded, posterior crest, which overshadowed the back of the skull and neck, was evidently of secondary growth, a practical necessity for the attachment of the powerful ligaments and muscles that supported the head (Plate I, figures 1–4).

The front part of the skull shows a very high degree of specialization, and the lower jaws have been modified in

* The large diagrams shown when this paper was read are most of them represented by reduced figures in the accompanying Plates, I–X.

connection with it. In front of the premaxillaries, there is a large, massive bone not before seen in any vertebrate, which I have called the rostral bone (*os rostrale*). It covers the anterior margin of the premaxillaries, and its sharp inferior edge is continuous with their lower border. This bone is much compressed, and its surface very rugose, showing that it was covered with a strong, horny beak. It is a dermal ossification, and corresponds to the pre-dentary bone below.

The latter, in *Triceratops*, is also sharp and rugose, and likewise was protected by a strong, horny covering. The two together closely resembles the beak of some of the turtles, and, as a whole, must have formed a most powerful weapon of offense.

In one skull figured (Plate I, figures 1–2), the rostral bone was free, and was not secured. This was also true of the pre-dentary bone and the nasal horn-core. Hence, these parts are represented in outline, taken from another specimen in which they are all present, and in good preservation. In another skull represented (Plate I, figure 4, and Plate II, figures 1–3), the rostral bone and nasal horn-core are in position, and firmly coössified with the adjoining elements.

The premaxillary bones are large, and much compressed transversely. Their inner surfaces are flat, and meet each other closely on the median line. In old specimens, they are firmly coössified with each other and with the rostral bone. Each sends upward a strong process to support the massive nasals. Another process, long and slender, extends upward and backward, forming a suture with the maxillary behind, and uniting in front with a descending branch of the nasal. The premaxillaries are much excavated externally for the narial aperture, and form its lower margin. They are entirely edentulous.

The maxillaries are thick, massive bones of moderate size, and subtriangular in outline when seen from the side. Their front margin is bounded mainly by the premaxillaries. They meet the prefrontal and lachrymal above, and also the jugal. The alveolar border is narrow, and the teeth small, with only a single row in use at the same time.

The nasal bones are large and massive, and greatly thickened anteriorly to support the nasal horn-core. In two of the skulls figured, these bones are separate, but in older individuals, they are firmly coössified with each other and with the frontals. The nasal horn-core ossifies from a separate centre, but in adult animals, it unites closely with the nasals, all traces of the connection being lost. It varies much in form in different species.

The frontal bones are quite short, and early unite with each other and with the adjoining elements, especially those behind them. The frontal or central region of the skull is thus greatly strengthened to support the enormous horn-cores which tower above. These elevations rest mainly on the postfrontal bones, but the supra-orbitals and the post-orbitals are also absorbed to form a solid foundation for the horn-cores.

These horn-cores are hollow at the base (Plate I, figure 3), and in general form, position, and external texture, agree with the corresponding parts of the *Bovidæ*. They vary much in shape and size in different species. They were evidently covered with massive, pointed horns, forming most powerful and effective weapons.

The orbit is at the base of the horn-core, and is surrounded, especially above, by a very thick margin. It is oval in outline, and of moderate size (Plate I, figure 1, *b*).

The postfrontal bones are very large, and meet each other on the median line. Posteriorly, they join the squamosals and the parietals. At their union with the latter, there is a median foramen (Plate I, figure 3, *x*) which apparently corresponds to the so-called "parietal foramen."* In old individuals, it is nearly or quite closed. When open, it leads into a large sinus, extending above the brain-case into the cavities of the horn-cores. This foramen has not before been observed in Dinosaurs.

The enormous posterior crest is formed mainly by the parietals, which meet the postfrontals immediately behind the horn-cores. The posterior margin is protected by a series of special ossifications, which, in life, had a thick horny covering. These peculiar ossicles, which extend around the whole crest, I have called the epoccipital bones (Plate I, figures 1–4, *e*). In old animals, they are firmly coössified with the bones on which they rest.

The lateral portions of the crest are formed by the squamosals, which meet the parietals in an open suture. Anteriorly, they join the postfrontal elements which form the base of the horn-core, and laterally, they unite with the jugals. The supra-temporal fossæ lie between the squamosals and the parietals.

The base of the skull has been modified in conformity with its upper surface. The basi-occipital is especially massive, and strong at every point. The occipital condyle is very large, and its articular face, nearly spherical, indicating great freedom of motion. The basi-occipital processes are short and stout. The basi-pterygoid processes are longer and less robust.

* The name usually applied to this aperture is misleading, as in *Chameleo* and some other reptiles, the foramen is not in or near the parietal bones. It may more properly be called the "pineal foramen."

The foramen magnum is very small, scarcely one-half the diameter of the occipital condyle. The brain-cavity is especially diminutive, smaller in proportion to the skull than in any other known reptile.

The exoccipitals are also robust, and firmly coössified with the basi-occipital. They form about three-fourths of the occipital condyle, as in some of the Chameleons. The supra-occipital is very small, and its external surface is excavated into deep cavities. It is coössified late with the parietals above, and with the exoccipitals on the sides (Plate I, figure 2).

The quadrate is robust, and its head much compressed. The latter is held firmly in a deep groove of the squamosal. The anterior wing of the quadrate is large and thin, and closely united with the broad blade of the pterygoid.

The quadrato-jugal is a solid, compressed bone, uniting the quadrate with the large descending process of the jugal. In the genus *Triceratops*, the quadrato-jugal does not unite with the squamosal. In *Ceratops*, which includes some of the smaller, less specialized forms of the family, the squamosal is firmly united to the quadrato-jugal by suture.

The quadrato-jugal arch in this group is strong, and curves upward, the jugal uniting with the maxillary, not at its posterior extremity, but at its upper surface (Plate I, figure 1). This greatly strengthens the centre of the skull which supports the horn-cores, and also tends to modify materially the elements of the palate below. The pterygoids, in addition to their strong union with the quadrate, send outward a branch, which curves around the end of the maxillary.

The palatine bones are much smaller than the pterygoids. They are vertical, curved plates, outside and in front of the pterygoids, and uniting firmly with the maxillaries. The vomers join the pterygoids in front, where they appear as thin bones, closely applied to each other.

The transverse bones give some support to the maxillaries, which are further strengthened by close union with the pterygoids. They meet the pterygoids behind, and the palatines in front.

The lower jaw shows no specialization of great importance, with the exception of the pre-dentary bone already described. There is, however, a very massive coronoid process rising from the posterior part of the dentary (Plate I, figure 1). The articular, angular, and surangular bones, are all short and strong, but the splenial is very long and slender, extending to the pre-dentary. The angle of the lower jaw projects but little behind the quadrate.

The Brain.

The brain of *Triceratops* appears to have been smaller in proportion to the entire skull, than in any known vertebrate.

The position of the brain in the skull does not correspond to the axis of the latter, the front being elevated at an angle of about thirty degrees (Plate II, figure 7).

The brain-case is well ossified in front, and in old animals, there is a strong septum separating the olfactory lobes.

Teeth of Triceratops.

The teeth of *Triceratops* and its near allies are very remarkable in having two distinct roots. This is true of both the upper and lower series. These roots are placed transversely in the jaw, and there is a separate cavity, more or less distinct, for each of them. One of these teeth from the upper jaw, represented by enlarged figures (Plate II, figures 8–11), and another tooth here exhibited, are typical of the group.

The teeth form a single series only in each jaw. The upper and lower teeth are similar, but the grinding face is reversed, being on the inner side of the upper series, and on the outer side of the lower series. The sculptured surface in each series is on the opposite side from that in use.

The teeth are not displaced vertically by their successors, but from the side. The crown of the young tooth, also with two strong roots, cuts its way between the alveolar margin and the adjacent root of the old tooth, sometimes advancing between the two roots, as might be expected.

The teeth in this family are entirely confined to the maxillary and dentary bones. The rostral bone, the premaxillaries, and the pre-dentary, are entirely edentulous.

Cervical and Dorsal Vertebræ.

The atlas and axis of *Triceratops* are coössified with each other, and at least one other vertebra is firmly united with them. These form a solid mass, well adapted to support the enormous head (Plate III, figure 1). The cup for the occipital condyle is nearly round, and very deep. The rib of the second vertebra is coösified with it, but the third is usually free. The centrum of the fourth vertebra is free, and the remaining cervicals are of the same general form, all having their articular faces nearly flat (Plate III, figure 2).

The anterior dorsal vertebræ have very short centra, with flat articular ends, and resemble somewhat those of *Stegosaurus*, especially in the neural arch (Plate III, figures 3–4).

The posterior trunk vertebræ have also short, flat centra, but the diapophyses have faces for both the head and tubercle

of the ribs, as in Crocodiles, a feature not before seen in Dinosaurs (Plate III, figures 5–6).

The Sacrum.

The sacrum was strengthened by union of several vertebræ, ten being coössified in one specimen of *Triceratops* (Plate IV). The middle or true sacral vertebræ have double transverse processes, diapophyses being present, and aiding in supporting the ilium. This character has been seen hitherto, in the *Dinosauria*, only in *Ceratosaurus* and some other *Theropoda*.

The main support of the pelvis was borne by four vertebræ, which evidently constituted the original sacrum. In front of these, two others have only simple processes, and apparently were once dorsals or lumbars. Three vertebræ next behind the true sacrum have also single processes, and the fourth, or last of the series, has the rib process weak, and not reaching the ilium (Plate IV). Seen from the side, the sacrum is much arched upward, and the neural spines of the true sacrum are firmly coössified. In the median region, the sacral vertebræ have their centra much compressed, but the last of the series are widely expanded transversely. The whole appearance of the sacrum is remarkably avian. The neural canal of the sacral vertebræ has no special enlargement, thus differing widely from that in *Stegosaurus*.

The Caudal Vertebræ.

The caudal vertebræ are short, and the tail was of moderate length. The first caudal has the anterior face of the centrum concave vertically, but flat transversely, and a short, massive neural spine with expanded summit (Plate V, figures 1–3). In the median caudals, the centra have biconcave articular faces, and weak neural spines. The distal caudals are longer than wide, with the ends nearly round, and concave.

The Scapular Arch and Fore Limbs.

The scapula is massive, especially below. The shaft is long and narrow, with a thin edge in front, and a thick posterior margin above the glenoid fossa. The distal portion has a median external ridge, and a thick end (Plate VI, figure 1, *sc*).

The coracoid is rather small, and in old individuals may become united to the scapula. It is sub-rhombic in outline, and is perforated by a large and well-defined foramen. No indications of a sternum have yet been found in this group.

The humerus is large and robust, and similar in form to that of *Stegosaurus*. It is nearly as long as the femur in one

individual, proving that the animal walked on all four feet. The radius and ulna are comparatively short and stout, and the latter has a very large olecranon process.

There were five well-developed digits in the manus. The metacarpals are short and stout, with rugose extremities. The distal phalanges are broad and hoof-like, showing that the fore feet were distinctly ungulate (Plate IX, figures 1–6).

The Pelvis.

The pelvis in this group is very characteristic, and the three bones, ilium, ischium, and pubis, all take a prominent part in forming the acetabulum. The relative size and position of these are shown in the diagram (Plate VII, figure 1), which represents the pelvic elements as nearly in the same plane as their form will allow, while retaining essentially their relative position in life.

The ilium is much elongated, and differs widely from that in any of the known groups of the *Dinosauria*. The portion in front of the acetabulum forms a broad, horizontal plate, which is continued backward over the acetabulum, and narrowed in the elongated, posterior extension. Seen from above, the ilium, as a whole, appears as a nearly horizontal, sigmoid plate. From the outside, as shown in the diagram, the edge of this broad plate is seen.

The protuberance for the support of the pubis is comparatively small, and elongated. The face for the ischium is much larger, and but little produced. The acetabular face of the ilium is quite narrow.

The pubis is massive, much compressed transversely, with its distal end widely expanded, as shown in the figure (Plate VII). There is no post-pubis. The pubis itself projects forward, outward, and downward. Its union with the ilium is not a strong one, and is similar to that seen in the pubis of *Stegosaurus*.

The ischium is smaller than the pubis, but more elongate. Its shaft is much curved downward and inward, and in this respect, it resembles somewhat the corresponding part of the pubis of the ostrich. There is no indication that the two ischia met closely at their distal ends, and they were probably united only by cartilage.

A comparison of this pelvis with that of *Stegosaurus* shows some points of resemblance, but a wide difference in each of the elements. The pubis corresponds, in its essential features, to the pre-pubis of *Stegosaurus*, but the post-pubis is wanting.*

* One pubis recently discovered, and represented in Plate VII, has a short, splint-like process, which may, perhaps, be a remnant of a post-pubic element, although it does not have the position of the post-pubic bone in other Dinosaurs.

The Posterior Limbs.

The femur is short, with the great trochanter well developed. The shaft is comparatively slender, and the distal end much expanded. The third trochanter is wanting, or represented only by a rugosity (Plate VIII, figure 1).

The tibia is of moderate length, and resembles that of *Stegosaurus*. The shaft is slender, but the ends are much expanded. The fibula is very slender, and the distal end was closely applied to the front of the tibia (Plate VIII, figures 2–3). In adult individuals, the astragalus is firmly coössified with the distal end of the tibia, as in *Stegosaurus*.

The metatarsal bones which were functional are rather long, but massive. Their phalanges are stout, and the distal ones, broad and rugose, indicating that the digits were terminated by very strong hoofs (Plate IX, figures 7–12).

All the limb bones and vertebræ in *Triceratops*, and the nearly allied genera, are solid.

The Dermal Armor.

Beside the armature of the skull, the body also in the *Ceratopsidæ* was protected. The nature and position of the defensive parts in the different forms cannot yet be determined with certainty, but various spines, bosses, and plates have been found, that clearly pertain to the dermal covering of *Triceratops*, or nearly allied genera. Several of these ossifications were probably placed on the back, behind the crest of the skull (Plate X), and some of the smaller ones may have defended the throat, as in *Stegosaurus*.

The remarkable extinct reptiles here briefly described present many characters which separate them widely from all other known Dinosaurs. Some of these characters are evidently the result of a high degree of specialization, but there are others that cannot be thus explained. The specialization evidently began in the skull, and there reached its greatest development. The peculiar armature of the skull has a partial parallel in the genus *Phrynosoma* among the recent lizards, and *Meiolania* among the extinct turtles. A suggestion of the parietal crest may be seen in the existing *Chameleo*, which offers other points of resemblance in its skull and skeleton. These features, however, indicate only a very remote affinity, and it is among the Dinosaurs alone that this group can be placed, as a distinct family, in the order *Ornithopoda*.

The main characters which separate the *Ceratopsidæ* from all other known families of the Dinosauria are as follows:

(1) A rostral bone, forming a sharp, cutting beak.
(2) The skull surmounted by massive horn-cores.
(3) The expanded parietal crest with its marginal armature.
(4) The teeth with two distinct roots.
(5) The anterior cervical vertebræ coössified with each other.
(6) The posterior dorsal vertebræ supporting, on the diapophysis, both the head and tubercle of the rib.

The *Ceratopsidæ* resemble, in various points, the *Stegosauria* of the Jurassic, especially in the vertebræ, limbs, and feet. The greatest difference is seen in the skull, but the pelvic arch, also, shows a wide divergence. In the *Ceratopsidæ*, there is no marked enlargement of the spinal cavity in the sacrum, and there is no post-pubis.

The characters above given are based upon fossils which I have personally investigated, including the type specimens of *Ceratops* and *Triceratops*, on which, mainly, the family *Ceratopsidæ* was established. The material now at my command includes the remains of many individuals, among which are portions of about twenty different skulls, and some of these are nearly perfect. In the memoir now in preparation, I shall fully describe and illustrate all the more important of these specimens, and likewise discuss their relations to allied forms.

The generic names, *Agathaumas*, *Cratæomus*, *Monoclonius*, and one or two others, have been given to fragmentary fossils, which may belong to this group, but these remains, so far as made known, appear quite distinct from those here described.

In conclusion, let me say a word as to how the discoveries here recorded have been accomplished. The main credit for the work justly belongs to my able assistant, Mr. J. B. Hatcher, who has done so much to bring to light the ancient life of the Rocky mountain region. I can only claim to have shared a few of the dangers and hardships with him, but without his skill and energy, little would have been accomplished. If you will bear in mind that two of the skulls, represented in the diagrams before you, weighed nearly two tons each, when partially freed from their matrix, and ready for shipment, in a deep, desert cañon, fifty miles from a railway, you will appreciate one of the mechanical difficulties overcome. When I add that some of the most interesting discoveries were made in the hunting grounds of the hostile Sioux Indians, who regard such explorations with superstitious dread, you will understand another phase of the problem. I might speak of even greater difficulties and dangers, but the results attained repay all past efforts, and I hope at no distant day to have something more of interest to lay before you.

EXPLANATION OF PLATES.

Plate I.

Figure 1.—Skull of *Triceratops flabellatus*, Marsh; seen from the left side.
a, nasal opening; *b*, orbit; *c*, supra-temporal fossa; *e*, epoccipital; *h*, horn-core; *h′*, nasal horn-core; *p*, pre-dentary; *q*, quadrate; *r*, rostral bone.
Figure 2.—The same skull; seen from behind.
d, dentary; *p*, parietal; *pd*, pre-dentary; *s*, squamosal.
Figure 3.—Skull of *Triceratops serratus*, Marsh; diagram; seen from above.
d, epijugal bone; *f*, frontal; *fp*, postfrontal; *j*, jugal; *m*, maxillary; *n*, nasal; *pf*, prefrontal; *pm*, premaxillary; *x*, pineal foramen.
Figure 4.—Skull of *Triceratops prorsus*, Marsh; seen from the front.
All the figures are one-twentieth natural size.

Plate II.

Figure 1.—Anterior part of skull of *Triceratops prorsus*, Marsh; side view; one-eighth natural size.
Figure 2.—Front view of same.
Figure 3.—The same; seen from below.
h′, nasal horn-core; *n*, nasal; *na*, narial aperture; *pm*, premaxillary; *r*, rostral bone.
Figure 4.—Pre-dentary of same individual; side view; one-eighth natural size.
Figure 5.—Top view of same specimen.
Figure 6.—Bottom view.
a, anterior end; *b*, upper border; *d*, groove for dentary; *s*, symphysis.
Figure 7.—Cast of brain-cavity of *Triceratops serratus*, Marsh; side view; one-half natural size.
c, cerebral hemispheres; *cb*, cerebellum; *m*, medulla; *ol*, olfactory lobe; *on*. optic nerve; *p*, pituitary body.
Figure 8.—Maxillary tooth of *Triceratops serratus;* outer view; natural size.
Figure 9.—The same tooth; side view.
Figure 10.—The same tooth; inner view.
Figure 11.—The same tooth; seen from below.

Plate III.

Figure 1.—Anterior cervical vertebræ of *Triceratops prorsus*, Marsh; side view.
Figure 2.—Fourth cervical vertebra of same series; back view.
a, anterior face of atlas; *d*, diapophysis; *n*, neural canal; *p*, posterior face of fourth vertebra; *r*, rib; *s*, neural spine of axis; *s′*, neural spine of third vertebra; *s″*, neural spine of fourth vertebra; *z′*, posterior zygapophysis.
Figure 3.—Anterior dorsal vertebra of same species; side view.
Figure 4.—The same vertebra; front view.
Figure 5.—Posterior dorsal vertebra of same species; side view.
Figure 6.—The same vertebra; front view.
a, anterior face of centrum; *h*, facet for head of rib; *p*, posterior face of centrum; *s*, neural spine; *t*, facet for tubercle of rib; *z*, anterior zygapophysis.
All the figures are one-eighth natural size.

Plate IV.

Figure 1.—Sacrum of *Triceratops prorsus*, Marsh; seen from below; one-eighth natural size.
a, anterior face of first sacral vertebra; *p*, posterior face of last sacral vertebra; *s*, neural spine of last vertebra; *z*, anterior zygapophysis of first vertebra; 1–10, transverse processes, left side.

PLATE V.

FIGURE 1.—First caudal vertebra of *Triceratops prorsus*, Marsh; side view.
FIGURES 2–3.—Front and back views of same vertebra.
FIGURE 4.—Median caudal of same species; side view.
FIGURES 5–6.—Front and back views of same vertebra.
FIGURE 7.—More distal caudal of same species; side view.
FIGURES 8–9.—Front and bottom views of same vertebra.
FIGURES 10–12.—Distal caudal of same species; side, front, and bottom views.
a, anterior face of centrum; *c*, face for chevron; *n*, neural canal; *p*, posterior face of centrum; *r*, rib; *s*, neural spine; *z*, anterior zygapophysis; *z′*, posterior zygapophysis.
All the figures are one-eighth natural size.

PLATE VI.

FIGURE 1.—Right scapula and coracoid of *Triceratops prorsus*, Marsh; side view.
FIGURE 2.—Right humerus of same species; front view.
FIGURE 3.—Left ulna of same species; front view.
cr, coracoid; *g*, glenoid fossa; *h*, head; *o*, olecranon; *r*, radial crest; *r′*, face for radius; *s*, suture; *sc*, scapula.
All the figures are one-eighth natural size.

PLATE VII.

FIGURE 1.—Pelvis of *Triceratops flabellatus*, Marsh; side view; one-twelfth natural size.
a, acetabulum; *il*, ilium; *is*, ischium; *p*, pubis.
FIGURE 2.—Pubis of *Triceratops prorsus*, Marsh; side view; one-eighth natural size.
FIGURE 3.—The same pubis; top view.
FIGURE 4.—The same; side view.
a, proximal end; *b*, face for ilium; *c*, pubic process; *d*, distal end.

PLATE VIII.

FIGURE 1.—Left femur of *Triceratops prorsus*, Marsh; front view.
FIGURE 2.—Left tibia of same species; front view.
FIGURE 3.—The same tibia; distal end; back view.
a, astragalus; *c*, inner condyle; *c′*, cnemial crest; *f*, face for fibula; *h*, head; *t*, great trochanter.
All the figures are one-eighth natural size.

PLATE IX.

FIGURE 1.—Metacarpal of *Triceratops prorsus*, Marsh; front view; one-eighth natural size.
FIGURES 2–3.—The same; side and back views.
FIGURE 4.—Terminal phalanx of manus of *Triceratops flabellatus*, Marsh; front view; one-fourth natural size.
FIGURES 5–6.—Side and back views of same.
FIGURE 7.—Metatarsal of *Triceratops prorsus;* side view; one-eighth natural size.
FIGURES 8–9.—Front and side views of same.
FIGURE 10.—Ungual phalanx of *Triceratops horridus*, Marsh; front view; one-fourth natural size.
FIGURE 11.—The same; side view.
FIGURE 12.—The same; posterior view.

PLATE X.

FIGURE 1.—Dermal spine of *Triceratops;* side view; one-eighth natural size.
FIGURES 2–3.—Front and top views of same.
FIGURE 4.—Dermal plate of *Triceratops;* top view; one-eighth natural size.
FIGURE 5.—Bottom view of same.
FIGURES 6–7.—Side and end views of same.
FIGURES 8–10.—Dermal plate of *Triceratops;* top, bottom, and side views; one-eighth natural size.
FIGURE 11.—Dermal ossification of *Triceratops;* side view; one-half natural size.
FIGURE 12.—Front view of same.

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THE

AMERICAN JOURNAL OF SCIENCE

[THIRD SERIES.]

Art. XX.—*On Gold-colored Allotropic Silver;* by M. Carey Lea. (Part I, with 3 Plates.)*

The object of the present paper (which may be considered as a continuation of that published in this Journal for June, 1889) will be:

1st. To describe the reactions of gold-colored allotropic silver.

2d. To show that there exists a well characterized form of silver intermediate between the allotropic silver previously described and ordinary silver, differing in a marked way from both.

3d. To prove that all the forms of energy act upon allotropic silver, converting it either into ordinary silver or into the intermediate form. Mechanical force (shearing stress) and high tension electricity convert it directly into ordinary silver. Heat and chemical action convert it first into the intermediate form, then into ordinary silver. The action of light is to produce the intermediate form only, and even the most prolonged action at ordinary temperatures does not carry it beyond this.

4th. To show that there exists a remarkable parallelism between the action of these forms of force on allotropic silver and their action on the silver haloids, indicating that it is not improbable that in these haloids silver may exist in the allotropic condition.

Reactions.

The most characteristic reactions of gold-colored allotropic silver are those with the strong acids. When normal silver

* Numbered I, II, III, being Plates XI, XII, XIII of the volume.

reduced with milk sugar and alkaline hydroxide is left in contact with strong hydrochloric acid even for several hours there is no action, and the silver after thorough washing dissolves in warm dilute nitric acid without residue. With allotropic silver similarly treated chloride is always formed. But strong hydrochloric acid instantly converts allotropic to ordinary silver and consequently only a trace of chloride is produced. By largely diluting the acid the conversion is retarded and the proportion of chloride is greatly increased. Thus for example when ordinary hydrochloric acid is diluted with fifty times its volume of water and is made to act on allotropic silver, about one-third of the latter is converted to chloride. Probably the whole would be but for the simultaneous conversion to normal silver. This double action is very curious and strongly differentiates allotropic from ordinary silver. Even with the same acid diluted with a hundred times its volume of water, there is a gradual but complete conversion to white silver accompanied by the production of a not inconsiderable quantity of silver chloride.

Neutral chlorides also act strongly upon allotropic silver even when much diluted. So sensitive is this form of silver to the action of chlorides that if in washing it on the filter, river water containing a mere trace of chlorides is by an oversight used instead of distilled water, a thin gray film of normal silver will form on the surface.

The reactions above described were obtained with the moist precipitate freshly prepared. By standing for some time even if kept moist it appears to undergo a change. When freshly prepared it is slightly soluble in acetic acid but after standing for a week or two ceases to be so.

Sulphuric acid diluted with fifty times its volume of water has no action upon normal silver. When made to act upon allotropic silver, it quickly converts it to normal but at the same time dissolves a little of it.

It is rather curious that the dry film of gold-colored allotropic silver seems to be more easily acted upon by some reagents than the moist precipitate. I have noticed for example that oxalic, citric and tartaric acids do not convert the moist precipitate to normal silver, but films on pure paper are gradually whitened by these acids. It is not a question of strength of solution, for the moist precipitate remained unchanged for twenty-four hours under the same solution which whitened the same material as a dry film.

Ammonia seems to be without converting action but dissolves a trace. It will be shown in a future paper that there exists a form of allotropic silver abundantly soluble in ammonia.

In those reactions in which allotropic silver acts the part of a reducing agent, as for example with potassium ferricyanide and permanganate and with ferric chloride, etc., its behavior differs from that of ordinary silver chiefly in showing greater activity. The difference is rather of degree than of kind. The formation by these reagents of colored films will be described at the end of this paper.

Intermediate Form.

Allotropic silver presents itself in an almost endless variety of forms and colors, gold-colored, copper-colored, blue and bluish green (these last in thin films red or purple). Most of these varieties seem to be capable of existing in two conditions, of which one is more active than the other.

If we coat a chemically clean glass plate with a film of gold-colored allotropic silver, let it dry, first in the air, then for an hour or two in a stove at 100° C., and then heat the middle of the plate carefully over a spirit lamp, we shall obtain with sufficient heat a circle of whitish gray with a bright, lustrous, golden yellow ring round it, somewhat lighter and brighter than the portion of the plate that has not been changed by heat. This ring consists of what I propose to call the "intermediate form."

Its properties are better seen by using a film formed on pure paper, one end of which is heated over a spirit lamp to a temperature just below that at which paper scorches. The change is sudden and passes over the heated portion of the surface like a flash. Examining the changed part, we find:

1st. That it has changed from a deep gold to a bright yellow gold color.

2d. When subjected to a shearing stress it *does not whiten or change color in the slightest degree.*

3d. It is much harder, as is readily perceived in burnishing it.

4th. It no longer shows the color reaction with potassium ferricyanide and ferric chloride, changing only by a slight deepening of color.

Of these characteristic changes the second is the most remarkable. The gold-colored silver in its original condition changes with singular facility to white silver: almost any touch, any friction, effects the conversion. If the paper on which a film is spread, is creased, the crease is found to be gray. Exposure to heat or to light destroys this capacity for change, and it is often lost by mere standing (even though protected from light) for a few weeks. This evidently indicates some remarkable molecular change. It will be noticed that the anomaly lies in this, that pressure instantly effects the

complete change from the original form to normal silver, heat effects the same change but with an intermediate stage at which stage *pressure no longer produces any action.*

The intermediate form is distinguished from normal silver almost solely by its bright yellow color and its higher luster. This last difference is very striking when a film on glass is heated in the manner above described. The central parts in changing to white silver become wholly lusterless, while the circle of "intermediate" retains all its original luster. Its continuity is still complete, so that if viewed through the glass, it still acts as a mirror.

This change may be either molecular or depend on dehydration.

The latter seems doubtful for the change can not be brought about by desiccation. Films on paper, on glass and also solid material were kept over sulphuric acid in vacuo for twelve days* without bringing about this modification (they were of course thoroughly protected from light).

Light is also capable of effecting to some extent this change, as will be described farther on.

Copper-Colored Allotropic Silver.

The color of allotropic silver depends to a remarkable extent on the amount of washing, which the freshly prepared material receives. With a short washing the material dries to a bright yellow gold color; with more washing to a reddish color; with still more, the color is a deep rich copper shade. The washing, when conducted in the ordinary manner, is exceedingly troublesome, the material soon begins to run through the filter and blocks it up. This trouble may be completely avoided by washing with a two per cent solution of Rochelle salt instead of pure water, until towards the end of the operation.†

* A longer time was inadmissible on account of the tendency to spontaneous alteration.

† The mode of preparing the gold and copper colored forms is as follows, the difference is in the length of washing only.

In a precipitating jar are placed,

Water	800cc
20% sol. Rochelle salt	200
40% sol. silver nitrate	50

In another vessel are placed,

Water	800cc
20% sol. Rochelle salt	200
30% sol. ferrous sulphate (crystallized)	107

(The substances must be added in the order above given and be mixed immediately before using. It is scarcely necessary to say that distilled water must be used exclusively.) As soon as the mixtures are made the iron solution is to be poured into the silver and vigorously stirred for some time. The white silver tartrate becomes almost immediately bright red, then deepens in color and finally becomes black.

Substances of a character nearly related to those that I have described in this and the previous paper, are obtained by acting on silver tartrate with stannous nitrate. The method is more troublesome and gives inferior results, the gold-colored product is less pure. A beautiful steel-blue substance obtained in this way was found to contain a considerable quantity of tin, probably present as stannic oxide, 10·87 per cent of tin corresponding to 13·80 SnO_2 was found by analysis. Another analysis gave 10·66 per cent corresponding to 13·61 SnO_2. In the first case the quantity of silver found was 83·61, in the second 84·12 per cent. These results do not lead to any satisfactory formula. The tin is no doubt present as an impurity and as the iron process gave far better results, the examination was not carried farther. Silver citrate gives similar results.

Action of different forms of Energy on Allotropic Silver.

1. *Action of Electricity.*

High tension electricity instantly converts gold-colored silver to the ordinary form. When paper covered with a film of gold-colored silver is held between the conductors of a Töpler-Holtz machine, each spark forms a gray dot of ordinary silver. A powerful discharge is not necessary; an inch spark from a small machine is effectual, even when the condensers are cut off. There is also a lateral action which is best seen when several slips of such paper are held loosely together and placed between the conductors. When the slips are opened a little the lateral branches are beautifully seen, playing through the silver. Their fine emerald-green color contrasts with the purplish shade of the spark.

When several pieces are in this way held between the conductors together, there is a transfer of silver from one piece to the other, so that the back of each piece of paper is blackened by silver carried over from the one behind it.

That the branching gray spots in this way formed, are normal silver, is easily proved by immersing the piece in a dilute solution of potassium ferricyanide. The part acted upon by electricity is not affected by the reagent, while the rest of the film shows the coloration characteristic of allotropic silver. In Plate I the upper figure shows a slip of paper, at one end of which electricity has been transmitted, and the figure below, a similar slip that has been subjected to the action of the ferricyanide, showing that where electricity has passed the silver has become normal and is not affected by the reagent.

2. Action of heat.

Allotropic silver is converted by heat to normal silver in either the wet or dry state.

Dry heat.—When films of allotropic silver on glass are placed in a water desiccator and are kept at 100 C. for eight or nine hours the central portions are converted into the intermediate form, while at the edges there is a border of grayish white ordinary silver. In fact the change to white silver at the edge commences before the central part is fully converted to the intermediate form.

At higher temperatures the change is much more rapid and better marked. At 180° C. the first effect is to darken a little: (this is usually the first effect of heat) this continues about five minutes. Continuing the heat for ten minutes more the slight darkening disappears and the film has a bright pure gold color sometimes with a slight salmon tinge. The change to the intermediate form is now complete, the film burnishes yellow and does not react with potassium ferricyanide. It is of interest to remark that the color reaction persists as long as there is a trace of unconverted material, *so that a film may burnish yellow and yet show a well-marked color reaction.* This is because most, but not all of the material has undergone conversion.

At 200° C. the film begins in about ten minutes to show a white border and in half an hour or thereabouts it whitens completely. In these experiments the best support for the film is chemically clean glass. Except that for testing the burnishing a film on paper is needed. The paper should be very pure.

Allotropic silver in the solid form heated to 180° or 190° for about fifteen minutes undergoes a similar change: whereas before it was easily pulverized, it is now almost impossible to reduce it to powder and the powder is yellow instead of being grayish black.

Moist Heat.—A film spread on pure paper and placed in distilled water maintained at 99° or 100° without actually boiling, at the end of half an hour is converted almost wholly to the intermediate form. It burnishes pure yellow but still shows traces of the color reaction.

A better plan of operating is to immerse a film spread on glass in distilled water and to place it in a desiccator with a water jacket. After keeping for twenty-four hours close to 100° C. the film has become pure white. It is not disintegrated by the change but may be detached from the glass in films exactly resembling ordinary silver leaf.

The effects of heat are shown in Plate I, lower pair of figures.

3. *Action of Mechanical Force.* (*Shearing Stress.*)

The slightest application of force suffices to instantly convert gold-colored allotropic silver to normal silver. A glass rod with a rounded end drawn lightly over the surface of a film on paper, leaves a white trace behind it. The force sufficient to cause this change is so slight that one might doubt its reality were it not for the decisive proof immediately at hand. First, there is the characteristic change of color: the film is as yellow and as brilliant as gold leaf; the line drawn by the glass rod is of pure white silver. Immersing the film in a solution of potassium ferricyanide the white lines simply change to gold color, whilst the film surface on which they are drawn passes through a brilliant succession of colors. (These effects are represented in Plate II, the uppermost figures.) For this use, freshly-made material should be employed, and the film itself should have been freshly spread on pure paper or card and used within a few hours after drying. This because of its easy partial passage, especially in thin films, to the intermediate state, in which it gives a yellow streak. (See also remarks as to partial conversion *ante.*)

When the experiment is performed under proper conditions the effect is very striking by reason of the instant conversion of the pure, deep yellow metal to perfect whiteness without a trace of color.

In an earlier communication to this Journal it was mentioned that, having taken with me on a journey several small vials containing gold-colored silver, they were found at the end of the journey to be all converted into white silver without having undergone any disaggregation, and retaining the original shape of the fragments. The white silver formed had the fine frosted white color of pure silver. This change was attributed to the friction of the fragments against each other, occasioned by the motion of the journey; a conclusion that was confirmed by finding that when cotton wool was forced into the empty part of the vial in such a way as to prevent all internal movement, the substance could be sent over a four-fold distance without alteration.

It was also observed (and this is a matter of special interest) that when a partial change had been effected by friction, this alteration went on, although the substance was left perfectly at rest, until it became complete. With time, all solid specimens of allotropic silver undergo this spontaneous change to bright white silver, apparently normal silver, even when thoroughly protected from light.

Out of over twenty specimens in tightly corked tubes, packed in a box and left in a dark closet for a year, not one

escaped conversion. Spread on paper or on glass and duly protected, the change is slower.

4. *Action of Strong Acids.*

The action of acids upon allotropic silver has been already described; it remains only to add here that the conversion to normal silver is entirely unaccompanied by the escape of gaseous matter; not a bubble can be detected by the closest observation.

By acting on dry films with dilute sulphuric acid it is easy to make the conversion gradual and so to trace its passage through the intermediate form.

With sulphuric acid diluted with four times its bulk of water and allowed to cool, an immersion of one or two seconds converts a film on glass or on pure paper wholly to the intermediate form. It is then bright gold-yellow but shows no color with the ferricyanide reagent. With sulphuric acid diluted with twice its bulk of water and used while still hot, the action is instantaneous and the allotropic silver is converted into light gray normal silver. The silver obtained in this way is very indifferent and gives no reaction with potassium ferricyanide, whereas even ordinary silver leaf gives a pale-colored reaction. (See Plate II, lower pair of figures.) The same acid after cooling acts more slowly; the product is more yellowish, owing to the presence of a certain quantity of the intermediate form.

5. *Action of Light.*

When allotropic silver is spread as a thin film on glass or on pure paper it may be preserved for a length of time apparently unchanged. This appearance is deceptive. From the moment that the film is formed a slow but steady change commences which can be best explained by supposing that a gradual polymerization takes place. Even after eight or ten hours' exposure to ordinary diffuse light a distinct loss of activity can be detected by careful testing with potassium ferricyanide. The change which occurs is in the nature of a tendency to a very gradual passage into what I have called the intermediate form in which the gold-yellow color remains unchanged while the chemical activity is lost or much diminished. Although a commencement of this change can be detected in a few hours, it goes on very slowly. By exposure to one or two days of summer sunshine (a much longer time is required in winter), the change is nearly complete. The exposed portions are lighter and brighter, and in solution of ferricyanide they color very slowly.

The question naturally arose whether light by a sufficiently long continued exposure could complete the change and convert allotropic to ordinary white silver. To obtain a decisive answer the following experiment was made:

At a window having a southeastern exposure and unobstructed light there were placed films on glass and on pure paper. Some of these were placed in a printing frame under an opaque design. The others stood side by side with the first but uncovered. The exposure was continued for four months from the end of January to the end of May. At the expiration of this time the uncovered paper and glass films were still bright yellow. But of those in the printing frame the exposed portions had become nearly white, while the protected parts retained their full deep gold color. It may at first seem strange that the uncovered pieces were less affected than those exposed in the frame. But this difference was always observed, namely, that if two films were exposed side by side, the one in a printing frame under glass, the other simply fastened to a board, the last mentioned was always the less affected. The explanation of this seeming anomaly lies in the fact that allotropic silver is always much more easily affected by heat than by light. The glass in the printing frame by exposure to sunlight becomes hot to the touch, and thus the film under it is kept at a temperature many degrees higher than that of the other film that is freely exposed to the air; the higher temperature aids the effect of the light.*

It appears, therefore, that the agency of light is somewhat similar to that of the other forms of energy but very much slower. Experiments made for the purpose demonstrated that it is the more refrangible rays that effect the change.

With light, the production of the intermediate form is never very satisfactory. Long exposures are needed, and before the change to the intermediate form is complete, the further alteration to white seems to commence. With heat the changes are much better marked.

When a film on pure paper has received an exposure of one or two days of summer sunshine under an opaque design, the exposed portions are sufficiently changed to have lost much of their chemical activity, so that when the film is plunged into a bath of potassium ferricyanide, the effect given in the lower figure of Plate III is obtained. The color represented is one of an immense variety of tints produced by this reagent on the

* Since this was written I find that both Herschel and Hunt noticed an analogous fact in the case of silver chloride, viz: that paper prepared with it darkens more rapidly under glass than when freely exposed; without, however, suggesting the cause, which is the same in both cases. I have observed that silver chloride darkens more rapidly when exposed under warm water than under cold to the same light in vessels side by side.

unaltered or active form. The upper figure of the same plate gives the effect of a very protracted exposure (as above described) on pure paper (or glass) under glass. With some kinds of sized paper, this effect is produced by a much shorter exposure; apparently owing to the presence of traces of a hyposulphite;* which appears to aid the action of light.

These seem to be not merely new facts but to belong to a new class of facts. No instance has been hitherto known of an element existing in so great a variety of forms and passing so readily under the influence of any form of energy from one to another of them.

It is evident that a connection must almost certainly exist between these varied transformations and the changes which many silver salts undergo through the action of light and other forces. This connection will form the subject of the second part of this paper. The present part will be concluded by a somewhat fuller description of the color reaction which is especially characteristic of allotropic silver.

The Color Reaction.

When allotropic silver is immersed in a solution of a substance readily parting with oxygen or sulphur or with a halogen, a film is formed which exhibits the colors of thin plates. Such phenomena are familiar and are seen in the blueing or yellowing of steel in tempering and the coloring of other metals when covered with films of oxide or sulphide. With allotropic silver the colors are very brilliant, probably because silver is the best of all reflectors for rays having a nearly perpendicular incidence, sending back about 90 per cent of such. Light gold colored silver gives the most brilliant effects.

The substances which produce these reactions are potassium ferricyanide and permanganate, ferric and mercuric chlorides, alkaline hypochlorites and sulphides, mixtures of potassium bichromate with hydrochloric or hydrobromic acid, solution of iodine, etc.

Potassium ferricyanide in a five or ten per cent solution is the best of these reagents because its action is more distinctive.

* The behavior of these varieties of paper led me to make inquiries of an intelligent paper manufacturer from whom I learned that every sort of paper pulp is now treated with chlorine. As any portion of the bleaching material left in the paper would eventually destroy its strength, it becomes necessary to add hyposulphite in excess to remove it. Accordingly every specimen of sized paper that I have examined contained hyposulphite, even the purest photographic papers were not free from it, though containing greatly less than most others. Apparently, the only difference is that with photographic paper more care is taken to avoid any considerable excess of hyposulphite.

In particular the blues which it gives are of great purity and the purples very rich. Ferric chloride gives beautiful tints, especially a peculiar glittering rose color. It must be very much diluted, until the solution loses its yellow color and takes a straw shade. It often happens that the characteristic color does not appear whilst the film is in the solution but a bronze shade only, the permanent color appearing only after the film has been dipped into water and blotted off. Potassium permanganate also gives rise to a beautiful succession of colors on allotropic silver but is somewhat uncertain in its action.

A ferricyanide is therefore the best reagent. As to the substance constituting the film which is formed, it is difficult to say whether it is silver suboxide or ferrocyanide. When potassium ferricyanide is allowed to act on moist allotropic silver suspended in it, and the action of the ferricyanide is carried to its limit, the silver is entirely converted into a yellowish white powder, consisting almost wholly of silver ferrocyanide mixed with a little silver ferricyanide.

Of the many varieties of ordinary silver which exist allotropic silver is convertible into two only. The high tension spark, heat, and acids convert it to dull gray silver: on this variety potassium ferricyanide has no action whatever, as will be seen by an inspection of the plates. Light under glass and pressure each convert allotropic to bright white silver, and on this form potassium ferricyanide acts slightly, converting the silver color to gold. It is needless to say that this gold color has nothing to do with allotropic silver: it seems to be produced in the following way.

When potassium ferricyanide acts on films of allotropic silver, its first effect is to deepen the gold color to a gold brown, passing rapidly on to other shades. The action on the bright white silver is very slight and apparently just reaches this gold stage, which corresponds to an air film having a thickness of from $0{\cdot}000150^{mm}$ to $0{\cdot}000160^{mm}$.

The succession of colors obtained on allotropic silver with potassium ferricyanide is as follows:

First Order.

Russet brown.
Brown red.

Second Order.

Rich and deep purple.
Dark blue.
Bright blue.
Pale blue.
Green russet.
Red.

Third Order.

Reddish purple.
Bluish purple.
Rich green.

The fourth order is not reached, for after this the colors become much mixed, probably the action is no longer sufficiently uniform. The other differences, beside the absence of the fourth order, as will have been observed, are that in place of the yellow of the second order corresponding to a thickness of air of 0·000432^{mm}, there is a green though of a more russet shade than that of the third order.

In the third order there is at no time a pure blue corresponding to 0·000602, but only a succession of beautiful red and blue purples, gradually passing into green.

There are few more beautiful experiments than to watch these changes. Purity of color, however, depends much on the purity of the paper employed. Want of this purity will often cut short the changes at the pale blue of the second order.

I have endeavored to give some idea of these colors in the Plates which accompany this paper, but it has proved to be a most difficult task. The colors represented are,

Plate I, purple and blue of the 2d order.

Plate II, purple of the 2d order and green of the 3d order.

Plate III, brown red of the 1st order.

It has not, however, been found possible to correctly reproduce the brilliancy and depth of color of the originals.

Philadelphia, Jan. 24, 1891.

(To be continued.)

EXPLANATION OF THE PLATES.

In each pair of figures the upper one represents the effect of exposing allotropic silver to some form of energy. The changes are in all cases similar in character.

In the lower of each pair of figures the effect is represented which would be produced by immersing the upper one in a solution of potassium ferricyanide. This affords proof of the completeness of the change by showing that gold-colored silver in passing into the ordinary form has lost its power of reacting with a ferricyanide. In these lower figures an attempt has been made to show some of the colors produced in this way. But they fall far short of the originals in brilliancy and intensity. These last are so remarkable that the lithographer who executed the work remarked that even an artist with a brush and palette of colors could not imitate them, and that therefore it was hopeless to expect to reproduce them by lithography—in other respects the Plates represent fairly well the changes that take place.

ART. XXI.—*The Flora of the Great Falls Coal Field, Montana;* by J. S. NEWBERRY. (With Plate XIV.)

IN the School of Mines Quarterly for 1887, I published a brief description of the coal basin which underlies the country about the Great Falls of the Missouri in Montana, and I am now able to add some facts of more than usual geological interest to those before known in regard to this coal field.

The Great Falls coal basin lies on the north slope of the Belt and Highwood Mountains; the strata all dipping toward the north. These mountains are subordinate folds of the Rocky Mountain system and are each composed of a granitic Archæan nucleus, locally overlain by a great thickness of Cambrian rocks which are best seen about Sulphur Springs. This formation must be at least 10,000 feet in thickness, and it underlies the surface from a point fifteen miles north of Sulphur Springs to near Townsend on the south. Splendid exposures of the same group are seen in Prickly Pear Cañon on the road from Helena to Great Falls. They consist of numerous alternations of thin bands of fine grained sandstone and argillaceous shale, generally metamorphosed into quartzite and slate. Near Sulphur Springs is an outcrop of limestone converted into marble. The prevailing color of the rocks of this group is gray at the surface, darker below. No distinct fossils were found in the slate though particles of carbonaceous matter abound everywhere. A shaly sandstone which apparently overlies all the series described is largely made up of Primordial trilobites.

On the summit and the north slope of the Belt mountains the Archæan granite nucleus is overlain by Potsdam sandstone full of *Scolithus* and casts of sea-weeds. There are here numerous large dykes of rhyolite which cut the granite and sandstone.

Succeeding the Potsdam sandstone is a great mass of Paleozoic limestone, sometimes blue, but mainly of a cream color, which has been cut by the streams draining northward into most picturesque cañons and valleys of which the sides are set with buttes imitating castles, fortresses, churches, etc., combining to form scenery equally attractive to the tourist and geologist. In the limestones are found both Silurian and Carboniferous fossils. North of the mountains the limestones are unconformably overlain by a series of sandstones, shales and fresh water limestones which include one large and several smaller seams of coal. These dip toward the north and are soon covered with a great and continuous sheet of glacial drift

that for the most part conceals the coal-bearing rocks and obscures the extent and outlines of the basin. The Missouri River has cut through the drift and exposed for many miles a series of pinkish sandstones which form the falls.

The age of this Great Falls coal basin was for a long time in doubt. Dr. Hayden first visited the locality, but found no fossils, and his experience was repeated by Dr. C. A. White and myself; although the exposures are ample on Sand Coulée and Belt Creek where the main coal has been extensively mined for years. Casts of stems and branches of trees are abundant in the sandstones, and the miners reported the occurrence of impressions of ferns in the shales over the coal, but after the most careful and thorough search nothing of the kind was found. The coal itself is of fairly good quality, the thicker seam consisting of several benches, of which the lower one, two and a half feet in thickness, makes a very good coke, and the whole will furnish an excellent steam coal for locomotives or stationary engines, will serve well as a household fuel, and is destined to be of great economic importance to the people who shall congregate in this prairie region.

Subsequent to my return from Great Falls, Mr. J. J. Hill, the president of the Chicago, St. Paul and Manitoba Railroad, in whose interests I made an examination of the coal basin, sent to me a slab of sandstone covered with Unios. This, as was to be expected, proved the fresh water character of the deposits, but the impressions were too ill defined to permit accurate, specific determination, and therefore threw no light upon their age. When the railroad along the north side of the Missouri, constructed with such unexampled rapidity by Mr. Hill, reached Great Falls, a cutting near the town passed through shales in which were numerous lenticular nodules of iron ore. Each of these contained a fern frond, a cycad leaf or a twig of a conifer. Some of them were collected by Mr. R. S. Williams of Great Falls, by whom they were sent to Professor Dana at New Haven. He submitted them to me for examination and I found that without exception they were species that had been described by Sir William Dawson from his Kootanie group [Lower Cretaceous] of Canada, or by Professor Heer from the Kome group of Greenland. These included *Sequoia Smittiana* Heer; *S. gracilis* Heer; *Zamites acutipennis* Heer; *Z. Montana* Dawson, etc. More recently Mr. Williams has sent to me a larger collection of fossil plants consisting mostly of ferns, from a different stratum in the Great Falls group. On opening the box I thought I identified a number of these with species described by Professor W. M. Fontaine from the Potomac group in Maryland and Virginia. But that there might be no mistake on a subject of such geo-

logical importance, I forwarded specimens of each species to Professor Fontaine asking that he would compare them with his Potomac fossils and decide upon their identity or difference. His letter in reply is so interesting that I herewith append a copy of it.

UNIVERSITY OF VIRGINIA, Oct. 15, 1890.

DR. J. S. NEWBERRY—

Dear Sir:—I have examined the plant fossils that you obtained from Great Falls, Montana, and sent to me for comparison with the fossils of the Potomac formation.

I find them to be as follows:

1. *Thyrsopteris rarinervis* F.
2. A plant near to *Podozamites distantinervis* F.
3. *Cladophlebis parva* F.
4. *Sequoia Reichenbachi* H.
5. *Pecopteris Browniana* F.
6. *Aspidium Fredericksburgense* F.
7. *Sphenolepidium Virginicum* F.
8. A plant allied to *Thyrsopteris brevifolia* F.
9. A plant near to *Cladophlebis distans* F.
10. *Thyrsopteris insignis* F.
11. *Carpolithus Virginiensis* F.
12. A plant near to *Cycadiospermum rotundatum* F.
13. *Pecopteris microdonta* F.
14. *Thyrsopteris brevipennis* F.
15. A plant near *Cladophlebis constricta* F.

The above named identities and resemblances are found on comparing the plants sent, with fossils of the Potomac formation described in Monograph XV of the publications of the U. S. Geological Survey.

The forms that I enumerate as "near" to named Potomac fossils, I hesitate to identify with them on account of the small amount or poor preservation of the material in hand available for comparison.

It should be stated that No. 9, which in foliage shows a facies like *Cladophlebis distans* has a fructification like that of some Aspidia and if identical with the Potomac plant this fact would remove it from the genus *Cladophlebis*.

Yours truly, W. M. FONTAINE.

The above identifications prove conclusively the general identity of the geological horizons of the Potomac group, the Great Falls group, the Kootanie group of Canada and the Kome group of Greenland, and confirm the view advocated by Professor Fontaine and myself that the Potomac group is Lower Cretaceous and not Jurassic.

Professor L. F. Ward in his review of the Potomac flora, (this Journal,) leaves the question of the age of the Potomac

group in doubt, but his opinion seems rather to incline to a Jurassic date. Professor O. C. Marsh considers the Potomac group Upper Jurassic, because he has obtained from it a number of reptilian remains of decided Jurassic affinities, but he tells me there are no species which he can identify with those of the Jurassic system, and we have been hitherto with little or no information about the vertebrate fauna of the Lower Cretaceous rocks of North America; so we need not be surprised to find it exhibiting marked Jurassic affinities. As pointed out by Professor Marsh the low grade and Mesozoic character of the mammalian fauna of the upper member of the Cretaceous system, the Laramie, would without other evidence lead to the conclusion that it was much older than it really is.

Professor Fontaine makes the Potomac group about the geological equivalent of the Wealden of Europe, but for the reason that it contains eighty known species of angiosperms out of a total number of three hundred and seventy-five, I am inclined to regard it as newer rather than older than the Wealden. The fossil plants of the Jurassic have been collected in large numbers and in many countries, but nowhere has a dicotyledonous plant been found in that formation, nor has an angiosperm been discovered in the Wealden of England or on the continent of Europe. The plants of the Wealden have been fully described by Dunker, Schenk and others, but all the species known are cycads, conifers or ferns. I recently had an opportunity, through the kindness of M. Dollo, of examining the plants found with the Iguanodons at Bernissart, and among them all there was not a trace of an angiosperm. This does not absolutely prove that the Potomac group is of more modern date than the Wealden, because the progress of plant life has been, as we know, somewhat unlike in different parts of the world, and the angiosperms may have begun their existence on the North American continent sooner than elsewhere, but it seems hardly possible that eighty or more species of arborescent angiosperms should have flourished on this continent before they had put in an appearance in the vegetation of the Old World. We may at least say that Professor Fontaine is fully justified in his conclusion that the Potomac is not older than the Wealden.

The relations of the Potomac to the Amboy flora are of special interest; the two formations are consecutive members of the Cretaceous system and the "variegated marls" of Fontaine or the "alternate sands and clays" of Uhler may be regarded as the southern extension of the Amboy clay group. Yet a long interval of time must have separated the epochs of the two formations, since the floras are so entirely different. Only a beginning has yet been made in the exploration of the

flora of the Amboy clays and yet we have obtained from them more than one hundred and fifty species. Probably when as much time shall have been given to the collection of plants from the Amboy clays as has been devoted to the collection of Potomac plants, the number of species will be as large, and better comparisons can then be made between the two floras, but it is evident that they are widely different. From the Amboy clays we have now taken about one hundred and fifty species of plants; of these more than one hundred, or a large majority, are angiosperms, whereas of three hundred and seventy-five species taken from the Potomac group only eighty are dicotyledonous. Besides this, it is doubtful whether any species yet found is common to the two formations.

The flora of the Amboy clays is most nearly allied to that of the Dakota group in the far west and the Atane group of Greenland, while one or two species are apparently identical with some taken from the Kome or Lower Cretaceous group. We may therefore fix the horizon of the Amboy clays with absolute certainty at Middle Cretaceous. With equal certainty we can assert that the Potomac, the Kootanie and the Kome groups represent perhaps distinct but closely related epochs of the Neocomian or Lower Cretaceous of the Old World.

As these determinations have for the most part been made from fossil plants, we must wait for the discovery of plants in the Cretaceous beds of Queen Charlotte's Island and the Shasta group of California before we can accurately correlate them with the Lower Cretaceous strata of Central North America. For this region the history of the Cretaceous age can already be written with a good degree of fullness and its more important incidents are as follows.

During the first half of the Cretaceous age the greater part of the continent of North America was out of water and therefore suffering erosion and receiving no deposition. During this interval a broad, circumscribed and almost inland sea occupied the place of the Gulf of Mexico, and the adjoining shores of South America, Mexico and Texas. In this sea marine deposits were forming which are the equivalents of the Lower Greensand or Neocomian. In time they attained in Chihuahua a thickness of not less than 4,000 feet and represent at least one-half of the Cretaceous age. During this time the area of the plains was out of water and toward the north bore on its surface lakes and marshes where the Great Falls and Kootanie groups were deposited. Beds of coal of considerable thickness and now of great importance were formed in these marshes. Up to the present time we have gathered thirty or forty species of the plants which from their debris formed the

peat that has now become coal. So far we have found among the remains of these plants not a single dicotyledonous leaf, but judging from the flora of the Potomac group and that of the Kome beds which have so many species in common with the Kootanie and Great Falls deposits, we may expect in the future to find a few angiosperms, the remains of the pioneers and advanced guard of the great army which here mingled with the cycads and conifers, and soon, through some inscrutable influence, mostly superseded them.

After the Kootanie epoch the eastern half of the North American continent was depressed and the sea gradually rose upon it, moving inwards, spreading a sheet of sea beach as far as it extended [the Dakota sandstone] and ultimately covering with 2,000 feet or more of marine sediments [the Colorado group] all the great depressed area lying between the Cumberland and Canadian highlands and the Wasatch.

The third great period of the Cretaceous age was the gradual emergence of this portion of the continent from the sea and the formation of the Laramie group with its great series of coal beds, its abundant land flora and its horned Dinosaurs. This closes the history of the Cretaceous age in North America.

The record which we have of the plant life of the continent during this long and varied interval is of special interest because we can reproduce the topography of the continent and in imagination clothe all its highlands with the successive phases of vegetation which we have disinterred in such abundance from the lacustrine and estuary deposits of its different epochs. The first Cretaceous forests were composed chiefly of cycads and conifers, showing great variety, because this was a part of their golden age. With these were numerous ferns more nearly allied to those of the present day than those of the Trias or Jura, several of the genera, as *Gleichenia*, *Asplenium* and *Aspidium*, continuing to the present day. This was the Kootanie epoch or that of the Great Falls coal basin, perhaps synchronous with, but more likely a little anterior to the Potomac epoch, in as much as we have found no angiosperms in the Kootanie flora.

Then came the Potomac group with a wonderful variety of conifers and cycads and with about one-fourth of its species angiosperms. Later still the epoch of the Amboy clays and Dakota sandstones when two-thirds to three-fourths of the species were angiosperms, but no palms had yet appeared.

Finally came the Laramie epoch, when the cycads and conifers constituted not more than one-tenth of the flora and the botanical aspects of the vegetation were essentially those of today, only palms were numerous as far north as the Canadian line, and the temperature was a little higher than at present.

List of Potomac species occurring elsewhere.

Equisetum Lyelli Mant., Wealden, Germany.
Pecopteris socialis?* Heer, Atane, Greenland.
Pecopteris Browniana Dunk., Wealden, Germany.
Sphenopteris Mantelli Brongn., Wealden, Germany.
Aspidium Oerstedi?* Heer, Atane, Greenland.
Aspidium Dunkeri Schimp., Wealden, Germany.
Gleichenia Nordenskioldi Heer, Kome, Greenland.
Dioonites Buchianus Schimp., Wealden, Germany.
Sequoia Reichenbachi Heer, Cretaceous [general].
Sequoia subulata Heer, Kome, Greenland.
Sequoia ambigua Heer, Kome, Greenland.
Sequoia rigida Heer, Kome, Greenland.
Sphenolepidium Kurrianum Heer, Wealden, Germany.
Sphenolepidium Sternbergianum Heer, Wealden, Germany.

Potomac Plants in Great Falls Group.

Sphenolepidium Virginicum F.
Carpolithus Virginiensis F.
Thyrsopteris rarinervis F.
Aspidium Fredericksburgense F.
Thyrsopteris insignis F.
Thyrsopteris brevipennis F.
Sequoia Reichenbachi Heer.
Pecopteris Browniana Dunk.
Cladophlebis distans F.
Pecopteris microdonta F.
Thyrsopteris brevifolia F.
Cladophlebis parva F.
Cladophlebis constricta F.

Great Falls Plants in Kootanie Group, Canada.

Sequoia Smittiana Heer.
Zamites Montana Dawson.
Zamites acutipennis, Heer.

Great Falls Plants in Kome Group, Greenland.

Sequoia Smittiana Heer.
Oleandra arctica Heer.
Zamites acutipennis Heer.
Zamites borealis Heer.
Sequoia Reichenbachi Heer.
Sequoia gracilis Heer.

* The materials on which Prof. Fontaine based the identification of these species are insufficient for satisfactory comparison; and while it is not impossible that the life of one or more species may have stretched over all the interval between the beginning and end of the Cretaceous age, stronger evidence of this fact than any we yet have must be furnished before we can consider it as established.

Since the above notes were written I have received, through the kindness of Mr. Williams, another collection of fossil plants from Great Falls. With several species before mentioned, it includes some which seem to be new, and of which brief descriptions are given below.

Chiropteris Williamsii, n. sp.

Pl. XIV, fig. 10, 11.

Fronds orbicular, oblong or lobed, two to four inches in diameter; petiolate, margins entire, nervation radiate, dichotomously forked and somewhat reticulated.

Of this remarkable fern I have many specimens, but none quite complete. At first sight they suggest the fronds of *Doleropteris* of the Coal Measures, but in that genus the nerves are fasciculate and divide by separation of the bundles and not by forking, and they never anastomose. In some specimens of the plant before us the nerves are buried in the parenchyma, showing that the consistence was thick and leathery; in others, perhaps more macerated, the nerves appear very distinct and rather coarse. A single small specimen shows a distinct stipe at the base.

This plant I have included in the genus *Chiropteris* with much hesitation, for it differs from the type species in having an orbicular or elliptical frond which is generally simple, though sometimes lobed, while in *C. Kurriana*, the type, the frond is flabellate and deeply lobed, almost palmate, thus approaching *Sagenopteris*, but in that genus the frond is distinctly palmate, the divisions being lanceolate, though springing from a common base. The nervation too of *Sagenopteris* is much more closely reticulated. In these respects the two genera would seem to be distinct. The nervation of our plant is essentially that of *Chiropteris*, the nerve branches anastomosing only at rare intervals, the meshes being many times longer than broad.

In the original notice of *Chiropteris*, by Dr. H. G. Bronn (Jahrbuch für Mineralogie, 1858), the fronds are represented as radiating in a whorl from a common base, and the nerves are neither figured nor described as inosculating, but Schimper in his Palæontologie Vegetale, (Vol. I, p. 643, Pl. XLIII) describes and figures the frond of *C. Kurriana*, as flabellate, digitately-incised, the nerves frequently forked and anastomosing to form narrow meshes. This description corresponds closely with some specimens of our plant, and while it is specifically distinct I do not feel justified, without more material, in separating it from the genus *Chiropteris*. Possibly facts will hereafter come to light which will require this to be set apart as the type of a new genus.

The horizon of the type specimen of *Chiropteris* is the upper Trias or Rhaetic. In the Jurassic rocks the genus has not been recognized, but its place has been taken by the allied *Sagenopteris*. Prof. Fontaine, in Monograph XV, U. S. Geological Survey, describes several species of *Sagenopteris*, but in these the form was very different and the nervation much more closely reticulated.

Formation and locality, Kootanie group, Great Falls, Montana. Collected by Mr. R. S. Williams and dedicated to him.

Chiropteris spatulata, n. sp.

Pl. XIV, figs. 1, 2.

Pinnules $1\frac{1}{2}$–2 inches long, spatulate in outline, midrib strong, lateral nerves well defined, coarsely reticulated.

The plants to which I have given the above name have precisely the nervation of the large rounded or lobate leaves, figured on the same plate and named *Chiropteris Williamsii;* and I have therefore provisionally placed them together. The form of both species is so different from that of the typical *Chiropteris*, that I have included them in that genus with much hesitation. The nervation is however so peculiar and so much alike in these two ferns, that while waiting for more material that shall permit a new genus to be defined upon them, I have concluded to group them together and under the old name.

Formation and locality, Kootanie group, Great Falls, Montana. Collected by Mr. R. S. Williams.

Zamites apertus, n. sp.

Pl. XIV, fig. 4, 5.

Fronds several inches in length by about one inch in width, pinnules leaving the rachis at nearly a right angle, linear, obtuse, somewhat widely separated; nerves invisible, sunk in the parenchyma.

This is a small species having the general aspect of *Zamites arctica*, Gœpp (Flora Arctica, vol. iii, p. 67, Pl. XV, figs. 1, 2), but is much more open in structure, the pinnules being separated by spaces sometimes as wide as themselves.

Formation and locality, Kootanie group, Great Falls of the Missouri, Montana.

Collected by R. S. Williams.

Baiera brevifolia, n. sp.

Pl. XIV, fig. 3.

Leaves flabellate, long petioled, one inch in width by one-half to three-quarters of an inch in length, deeply lobed; lobes truncate, sometimes undulate and slightly contracted at the summit.

This species has much the aspect of *B. pluripartita*, Schimper (Palæontologie vegetale, vol. i, p. 423, Pl. XXXI, fig. 12,) (Schenk, Flora Nordwestdeutschen Wealdenformation, p. 10, Pl. III, figs. 1–8), but is much smaller. Possibly, however, it is merely a depauperate form or smaller variety of that species. Further material will be required for deciding this question. However, the specimens which we have are not half the size of those figured by Schimper, Schenk, Dunker and Brongniart. The specimens of *B. pluripartita* (*Cyclopteris digitata*, Dunker) are all from the Wealden of different localities in Europe.

Formation and locality, Kootanie group, Great Falls of the Missouri, Montana.

Collected by R. S. Williams.

Cladophlebis angustifolia, n. sp.

Pl. XIV, fig. 8.

Pinnæ several inches in length by one inch in maximum width; pinnules ten to twelve mm. in length by three mm. in width at base, distinctly separated, attached to the entire base, curved or falcate in form, subacute or obtuse at summit; nervation open, strong.

This plant resembles *C. falcata* Fontaine (Monog. XV, p. 72, Pl. V, figs. 1–6), but the pinnules are smaller, narrower and less acute.

Formation and locality, Kootanie group, Great Falls of the Missouri, Montana.

Collected by R. S. Williams.

Sequoia acutifolia, n. sp.

Pl. XIV, fig. 7, 7a.

Leaves crowded, from one-quarter to one-half an inch in length, wedge-shaped, rounded or abruptly contracted at the base, summit long pointed, very acute.

Only one twig of this tree is contained in the collection, but its leaves are so peculiar that I feel quite justified in considering it a new species. Its most striking feature is the wedge-shaped outline of the leaves which are broadest near the base and are drawn out in a long and very acute point. In the Cretaceous rocks of Vancouver's Island occur twigs of a species of *Sequoia* to which I have given the name of *Sequoia cuneata* because they are so decidedly wedge-shaped, but in that species the leaves are spatulate, broadest near the rounded summit and terminate below in a wedge-shaped base. In the species now under consideration the leaves have quite an opposite form; being broadest at or near the base and terminating above in a long drawn acute point.

Among all the living and fossil species of *Sequoia* there is no other known to me that has leaves of this peculiar form.

Formation and locality, Kootanie group, Great Falls, Montana.

Collected by Mr. R. S. Williams.

Podozamites nervosa, n. sp.

Pl. XIV, fig. 6.

Leaflets, four inches in length, lanceolate, broadest toward the base, subacute at the summit; nerves parallel, distant, strong.

This is a leaflet of a frond of a strong-growing species of zamites similar to Heer's *B. marginatus*, but differing from that in its much more remote parallel and distinct nerves. Only one specimen has been as yet received from Mr. Williams, and more will be needed before we can define the range of variation in the pinnules.

Oleandra arctica Heer.

Pl. XIV, fig. 9.

The specimen figured agrees in all essential characters with Heer's plant from the Kome group, Greenland, described in vol. iii of his Flora Arctica. A much larger and finer specimen has been sent to me by Mr. Williams, but the figure now given will permit the identification of the plant wherever found. This is interesting as another connecting link between the flora of the Great Falls group, and that of the Lower Cretaceous of Greenland.

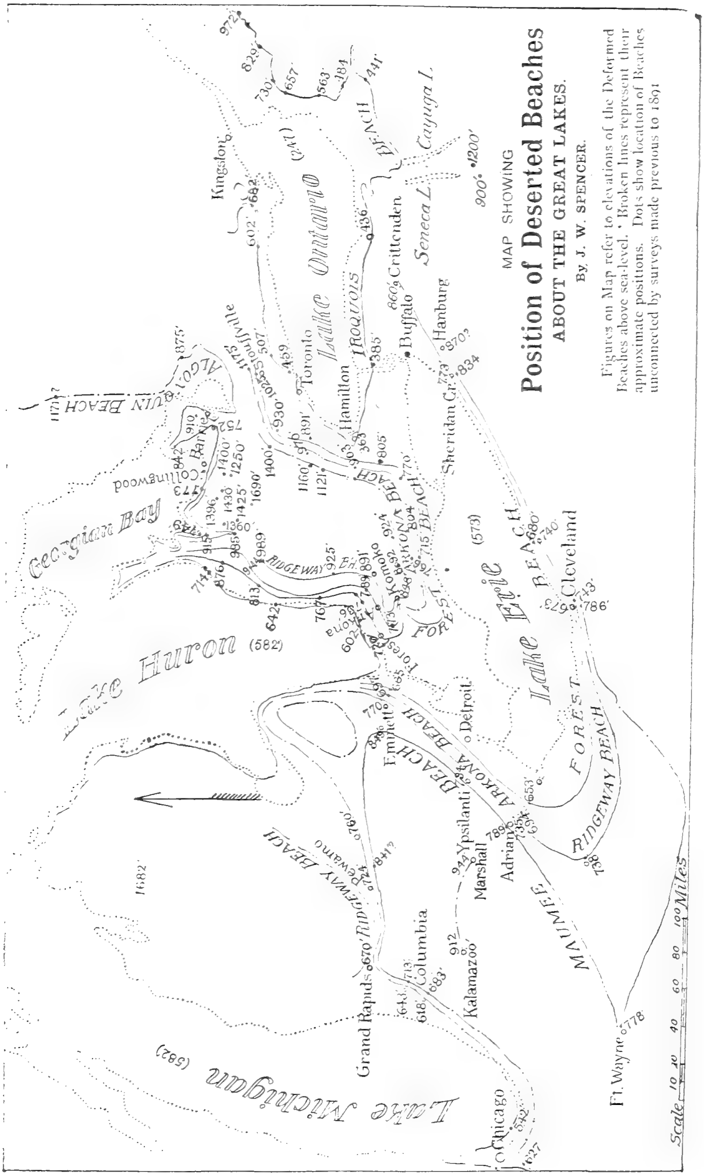
ART. XXII.—*High Level Shores in the region of the Great Lakes, and their Deformation;* by J. W. SPENCER.

CERTAIN of the deserted shores about the Great Lakes have been already described in the author's papers on the Iroquois and Algonquin Beaches.* The Iroquois Beach is confined to the Ontario basin, and the Algonquin Beach still defines the deserted shores of the lake which embraced Georgian Bay and Lakes Huron, Michigan and Superior during the episode when they formed one expanded sheet of water. But above these beaches there are others not confined to any of the existing basins, but at elevations which required all of the lakes to have been united into one sheet of water. This sheet, whose dimensions have only in part been surveyed, I named Warren Water.† As the southern and southwestern shores have been surveyed for a length of eight or nine hundred miles, and several hundred miles of the coast line about the former large island, now represented by a part of the Province of Ontario, are known, the work seems to justify this publication without further delay (see map, p. 202).

In the investigation of the high beaches, I acknowledge with great pleasure the assistance of Prof. W. W. Clendenin and Prof. W. J. Spilman, who accompanied me in the researches. Respecting the beaches upon the Canadian side of the lake, no other systematic exploration has been made. Four or five years ago, some of our friends put ice dams, where beaches are well developed, to hold up the waters whose waves built up the beaches upon the southern side of Lake Erie. In Michigan, the record was nearly as meagre, although

* The Iroquois Beach: A chapter in the Geological History of Lake Ontario. Trans. Roy. Soc. Can., p. 121, 1889. Deformation of the Iroquois Beach and Birth of Lake Ontario. This Journal, vol. xl, p. 443, 1890. Deformation of the Algonquin Beach and Birth of Lake Huron. Ibid., vol. xli, p. 12, 1891.

† See Notice of Iroquois Beach, Science, vol. xi, p. 49, Jan. 27, 1888.


MAP SHOWING
Position of Deserted Beaches
ABOUT THE GREAT LAKES.
By J. W. SPENCER.
Figures on Map refer to elevations of the Deformed Beaches above sea-level. Broken lines represent their approximate positions. Dots show location of Beaches unconnected by surveys made previous to 1891
Lake Huron
Lake Michigan
Lake Erie
Lake Ontario
Georgian Bay
Scale 10 20 40 60 80 100 Miles

some of the beaches had been used as roads since the days of Indian habitation. But in Ohio, more or less work had been done, which will be referred to in its proper place. Upon both sides of the St. Clair River, a succession of beaches may be seen, in ascending inland over the slowly rising plains. The beaches are of the same character as those described in the author's earlier papers upon ancient shores. But they appear to represent a rather shorter time in formation than the Iroquois and Algonquin Beaches.

THE FOREST BEACH.—Upon the Canadian side of the St. Clair River, the first important deserted shore line, above the Algonquin Beach, may be seen at Forest—and hence I will name it the Forest Beach. This has been explored in both directions from Forest, as shown on the map, with elevations as in the table—these being instrumentally levelled.

	Feet above the Sea.
Lake Huron	582
Forest	720
East of Parkhill	736
Near Bayfield	767
Ripley	813
Walkerton (terrace in valley)	825
Paisley (terrace in valley)	860
East of Burgoyne	876
Rockford (spit across valley)	915
Barrie (on insular ridge)	910

East of Rockford the country is not favorable for the identification of the old beaches, as they were interrupted by the promontory of Blue Mountains extending into the former sheet of water, but on it various rock-terrace shore-lines are engraved. On the drift hills farther eastward, ridges reappear at elevations above the Algonquin Beach, which would point to their identification with the Forest Beach. In this north-eastward direction our survey was discontinued.

From Forest, the beach has been explored, upon the northern side of Lake Erie, and the equivalent terraces traced to north of Lake Ontario. The measured elevation at various points are:

	Feet above the Sea.
Komoko (terrace in valley)	722
White's Station (south of London)	715
Near Waterford	770
Brantford	805
Pushlinch Church (rock-terrace)	840
Georgetown (terrace)	891
Mono Road (terrace)	930
North of Stouffville (terrace)	1025

The terrace is a strong topographical feature, especially after passing over the Niagara escarpment near Georgetown. The differential elevation of the Forest Beach, in the extreme southwestern part of the Province of Ontario, is 1·44 feet per mile in a direction of N. 28° E. But northeast of Toronto this warping has increased to three feet per mile as it trends north of east, with the direction of the maximum rise not determined. This warping is in harmony with the deformation of the Iroquois Beach, in the same region, being only slightly in excess, as it should be. No attempt has been made to explore the extreme eastern and northern portions of the Forest Beach, around the island of the Province of Ontario.

THE ARKONA BEACH.—This beach is less perfect than the Forest Beach. It is prominent at Arkona, rises to 789 feet east of Ailsa Craig, passes by Varna and Ripley, and near Walkerton has an elevation of 944 feet. At Chatsworth, the spit across the valley at 985 feet, probably belongs to this shore-line. No further explorations have been made in this direction. Southwest of Arkona, the beach has an elevation of 773 feet at Waterford; 754, on a river terrace near Komoko; 735 (?) at Taylor; 776, on the plains at St. Thomas; 792 at Cornith; 804 at Delhi. Beyond this point there are shore remains, at 903 feet near Paris; a terrace at Limehouse, at 970, and at Stouffville, a gravel ridge skirting higher land, at 1175 feet. These latter fragments may be the equivalents of the Arkona Beach. But these last named shore-lines continue the upward succession of deserted water-lines even if not identical with the Arkona Beach. This beach is imperfectly explored, and is more or less interrupted, like other shore-lines, in the lake region as well as those nearer the sea coast, such as on Mt. Desert Island.

RIDGEWAY AND HIGHER BEACHES.—Above the Arkona beach, the next shore-line is here named the Ridgeway Beach, (as this is a suitable name for its counterpart in Michigan). Its elevation, near the following places, is:

	Feet above the Sea.
Komoko	848
Lucan Junction	891
Hensall	925
Lucknow	989

As the object of our surveys was for the more especial exploration of the lower beaches, the explorations were not carried throughout the distribution of the higher beaches. But beaches, spits across valleys, and terraces carved out of the Niagara escarpment were seen in many places at altitudes which would correspond to the continuation of this shore-line. Back and above this beach, there is a belt of flat plains, corres-

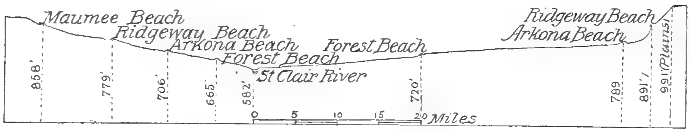
ponding to the frontal plains of still higher deserted coast-lines. Indeed, in the fragments seen, several other still high coast-lines are recorded. The altitudes of several of these are here given, and those marked with an asterisk are in topographical positions that would permit of their identity with the Ridgeway Beach, which has not however been continuously traced between all the points.

	Feet above the Sea.
Seven miles south of London	*882
" " "	872
" " "	862
Near Ingersoll	*924
"	911
" (terrace)	903
Corwhin (rock-cut terrace with gravel floor)	*1127
Acton (rock-cut terrace with gravel floor)	*1160
Near Mono Mills (rock-terrace)	1400 (bar.)
" " (gravel terrace)	1375 (bar.)
" " (terrace)	1200 (bar.)
West of Collingwood (rock-terrace)	1400 (bar.)
West of Clarksburg (beach)	1396
" " (beach)	1372
" " (rock-terrace)	1262
" " "	1225
Duncan (rock-terrace)	1260 (bar.)
N. E. of Flesherton (terrace with gravel floors)	1430 (bar.)
Dundalk	1690
Proton (plains)	1613
South of Markdale (terrace)	1425 (bar.)
" "	1400 (bar.)
Markdale Station (terrace)	1360
2 miles north of Berkley (gravel spit)	1260 (bar.)
Arnott (terrace)	1067

The beach remnant, in the region of Dundalk, is only twenty feet below the highest point of land, which once formed a small island. From this point down to sea-level, there is abundant proof, in the beaches, spits, sea-cliffs, and cut terraces that there was a long succession of intermittent episodes of subsiding waters from the highest lands of the peninsula of Ontario—lands often higher than the highlands north of the Great Lakes, which now constitute the Laurentian Mountains—care having been taken to distinguish these named structures from those gravel deposits belonging to the older drift episodes. Even after allowing for the amount of more recent terrestrial warping, these higher shores of Ontario rise far above much of the land to the south of the lakes. All of the deserted water-margins are more recent than the drift deposits, and some

of them are cut out of the third series of till, which covers ridges and plains of much of the highlands of Ontario. The highlands of the peninsula then rose up as a growing island out of the receding Warren Water.

The position and relative heights of the beaches of the two sides of the St. Clair River are seen in the following section,



which represents a profile across them along a nearly east and west line. Making allowance for the terrestrial deformation between the beaches themselves, it will be readily seen that there is only a slightly greater amount of rise between members of the series upon the eastern side than upon the western, and this is in harmony with all the observations elsewhere about the lakes. Hence, I have been forced to accept the identity of the two sets on the opposite sides of the St. Clair River, as there are no important intervening shore-markings, on the plains between the named ridges, although those upon the western side are more sandy than on the eastern.

THE FOREST BEACH skirts the plains at the head of Saginaw Bay and passes around the thumb of Michigan. About five miles west of

	Feet above the Sea.	
Port Huron, it is duny with an elevation of	665	
East of Berville	668	
Sylvania	663	
East of Defiance (Gilbert)	653	
Cleveland	673	(bar.)
Madison	680	
Sheridan Centre, N. Y., (Gilbert)	773	
Crittenden, N. Y., (Gilbert)	860	

THE ARKONA BEACH has an elevation of—near

Goodall	697
Denton	694
Blissfield (ridge duny)	694
Cleveland	708

A record of this shore-line is more meagre than the last. Both of these beaches have been more or less surveyed in Ohio by the late Geological Survey of that State,* and Mr. G. K. Gilbert has measured the continuation of the lower for some distance beyond the State line, into New York. The Lower,

* Geology of Ohio, vol. i, map, p. 549.

or Forest Beach, is identical with that numbered four of the Ohio Survey, at the head of Lake Erie. Spits and spurs are frequently given off from these beaches, and add some difficulty to the surveying, especially in Ohio.

THE RIDGEWAY BEACH, or next highest shore-line, is the most important of the whole series, as it has been explored for the greatest distance, and is perhaps the easiest of identification. On it, many long stretches of dry roads, bounded by muddy plains, have been used from the first settlement of the country. The other ridges have also in places been used for roads, but to a less extent.

Elevations on the Ridgeway Beach determined by Leveling.

	Feet above the Sea.	
Lake Michigan and Lake Huron	582	
Lake Erie	573	
Beach near Chicago (calculated)	526–542	
Near Columbia, Mich	618	(bar.)
Allegan (terrace) in valley	643	
Grands Rapids	670	
Pewamo	724	
Chapin	760	(bar.)
East of Emmett	770	
Near Berville	753	
East of Ypsilanti	734	
West of Lenawee Junction	735	
Defiance, Ohio	738	(Gilbert.)
Cleveland	743	(Geol. Ohio.)
Madison	740	(bar.)
Sheridan Centre, N. Y.	834	(Gilbert.)
Hamburg, N. Y	870	(+ or −20) (Gilbert.)

Throughout the windings, this coast line has been explored for eight or nine hundred miles. The highest beach south of Chicago is only 42 feet above the lake, and this probably belongs to a series to be noted hereafter, and from it the position of the Ridgeway Beach is calculated. The country southeast of Lake Michigan is very sandy and duny, and thus it is more difficult to recognize the exact water-margins than farther east where the beaches are narrow ridges between clay plains. From Grand Rapids to Pewamo the beach passes through a strait between high lands on both sides. This depression is now occupied by the Grand River, between the head waters of which, and those draining into Saginaw Bay, the divide does not exceed a height of one hundred feet above the lakes, although the land rises many hundred feet on both sides, Indeed, from even west of Pewamo the low embayment widens

and forms the broad flat plains at the head of Saginaw Bay. But these plains, for half their length, are drained to the west by the Grand River, although they were formerly the floor of the lately enlarged Saginaw Bay. Hence, the topography shows the reversal of the drainage, by a slight uplift towards the east and north, which in the region of Pewamo amounts to about a foot per mile. This rise continues to Chapin, whence the beach rises towards the northeast and passes around the thumb of Michigan, and descends to about a mile east of Emmett. From the crossing of the beach, east of Ypsilanti, to Lenawee, there is no terrestrial warping as shown by instrumental measurements. The occurrence of this beach, although not identified throughout any distance, was described by Prof. A. Winchell.* From Lenawee, the Ridgeway Beach extends into Ohio, and becomes identical with the beach of the Maumee Valley, called by Mr. Gilbert number three.† Thence it extends eastward with natural interruptions. From Ohio it has been traced into New York by Mr. Gilbert. The portion south of the western half of the lake practically shows no deformation, but between Madison and Sheridan Centre, it rises about a foot per mile, while the lower, or Forest Beach rises in the same distance only about three quarters of a foot, although eastward of that point the last named beach rises two feet per mile.

At the head of the Maumee valley, a fragment of a beach, about thirty feet higher than the Ridgeway Beach, was described in the Geology of Ohio.‡ This, however, is only occasionally met with. A beach at Grand Rapids, Mich., at 700 feet, and a terrace near Allegan at 689, may be the equivalent of that in Ohio.

THE MAUMEE BEACH.—This is the next highest of the well defined beaches which have been studied. That, at 42 feet above the lake at Chicago, is probably identical with the beach, which has been traced from the southeastern side of the lake, as it is in the topographical position in which we would expect to find it. But the country is a very sandy and duny.

The beach is identical with Mr. Gilbert's number one at the head of the Maumee valley, and hence the suitability of the name. When the water was at this level, Mr. Gilbert regarded the outflow of the lake as by the Wabash River. The divide, at the head of this river, from the Maumee drainage was nearly fifty feet below its surface.§ But it was not then known that this deserted shore extended throughout the Saginaw valley to the Michigan basin. Nor had the moderately complete

* Geology of Washtenaw County, by A. Winchell, 1881.
† Geology of Ohio, map, p. 549. ‡ Ibid.
§ Geology of Ohio, vol. i, p. 551.

and accurately measured Ridgeway Beach been surveyed, and the warping movements measured therefrom. From the present information, it will at once be seen that the same sheet of water had also access to the Mississippi drainage by the depression at the head of Lake Michigan, which is twenty feet or more below the highest beach in the vicinity, the probable equivalent of the Maumee Beach, east of the lake, now about a hundred feet above its surface, near Columbia.

Elevations of Maumee Beach near:

	Feet above the sea.
Columbia, Mich. (dunes rise to 699 feet)	683
Allegan (dunes to 740, terrace)	713
East of Pewamo (barometric)	841
Imlay	849
Berville	817
Ypsilanti (terrace)	784
Adrian	789
Fort Wayne (Gilbert)	788 to 778
Cleveland (Geol. Ohio)	786

Amount of Warping in the preceding Beaches.—Across the State of Michigan, the Maumee Beach records a differential eastward or northeastward elevation of scarcely more than a foot per mile, while that of the Ridgeway Beach in the same direction is a little less than a foot per mile.

West and south of Lake Erie the unequal movement is reduced to almost zero. But east of Lake Erie the uplift reaches two feet per mile as recorded in the Forest Beach.

East of Lake Huron, the Arkona Beach rises to the northeastward at 1·71 feet per mile, and the parallel and younger Forest Beach at 1·5 feet. The still younger Algonquin Beach* rises 1·33 feet, east of Lake Huron. This warping increases so that east of Georgian Bay it amounts to 4·1 feet per mile, in direction N. 25° E. The explored beaches north of Lake Erie have an accelerated rise, so that, northwest of Lake Ontario, it amounts to 3 feet or more per mile, in the higher water margins. If the higher shore-lines in the Adirondacks could be and were surveyed we would expect a differential elevation to the northeast of more than five or six feet per mile, as that amount has been measured in the lower Iroquois Beach.† But most of the differential crust movement has been since the Iroquois and Algonquin episodes.

Higher coast lines.—There were sheets of water preceding the Maumee episode, for across the higher lands of Michigan, there are extensive belts of flat land or plains

* "Deformation of the Algonquin Beach," etc., this Journ., vol. xli, 1891, p. 15.
† "Deformation of the Iroquois Beach," etc., this Journ., vol. xl, 1890, p. 447.

often covered in part with gravel floors, and in part with silt. They are the exact counterpart of the plains in front of the lower beaches, although more eroded by the streams cutting down to the lower levels. Thus extending from the vicinity of Kalamazoo there is an extensive plain, with a floor of well-rounded gravel, bounded on the south by ridges but with a generally open and descending country to the north. On this plain, I have traveled for forty miles to eastward of Marshall, and could see in it no other history than that of the bottom of some bay in front of ridges of drift hills towards the south. The barometric height taken from the station at Kalamazoo gives the plain or terrace an elevation of 912 feet above the sea. Farther eastward the measurements reached 944 feet. In the valleys, there are lower river terraces probably corresponding to the Maumee Beach. The amount of warping in the region is very little. It has also been noted that there is scarcely any deformation south of Lake Erie until passing eastward of Madison, Ohio. It is well known that there are at last four troughs in Ohio connecting the Erie valley with that of the Ohio River having summit floors at elevations of between 909 and 940 feet above the sea, composed of drift materials, and that there are terraces at the northern end of these valleys.* The terraces at the head of the Mahoning valley is a good example. It is probable that the gravel plains of Michigan and the terraces in Ohio, connected with these meridional troughs, are identical in age. But here is room for investigation. In Michigan, there are other and higher gravel flats than those just referred to.

Professer Rominger records beach-like deposits at 1,682 feet above the sea on the highest lands near the northern part of the lower peninsula of Michigan.† Professor E. Desor noticed other similar deposits at considerable elevations in the northern peninsula of that State.‡ Mr. A. Murray long ago reported a series of beaches on the northern side of Lake Superior.§ Professor H. Y. Hind observed terraces at Great Dog Portage, north of the same lake at 1,435 feet.‖ Other beaches at 1,100 feet have been reported in Wisconsin. None of these I have seen, and do not know which of them, except those north of Superior, belong to true beaches, for I have everywhere had to distinguish between plain shore structures and those forms which go under the name of kames, osar, etc.

* Geology of Ohio, vol. ii, p. 47.

† Geology of Michigan, vol. iii, p. 10.

‡ See Beaches, etc., between Lakes Mich. and Sup., by E. Desor in Foster and Whitney's Report, vol. ii.

§ Geology of Canada for 1863.

‖ Report upon Assiniboine and Saskatchewan Expedition, 1859, p. 120.

It is due, in part, to the delay in systematic investigation, that we owe our ignorance of the high-level shore-markings in New York. Terraces and delta deposits occur about Seneca and Keuka Lakes and elsewhere in New York. The gravel plain at Horseheads at the divide, south of Seneca Lake valley has an elevation of 900 feet. The valley is a mile or more wide, with free drainage towards the south. Is this shore deposit the equivalent of the Forest or some other beach? In a lateral valley, immediately to the east of Horseheads, there is a well marked terrace at an elevation of 1,200 feet. This terrace-plain could not have been formed unless the waters filled the valley at Horseheads, which is only three or four miles away, to a depth of 300 feet.

The terraces of the Genesee River, up to 1,900 feet above the sea, or 250 above the river, and the records north of the Adirondack Mountains tell the same story of water everywhere, at elevations indicating one vast sheet, extending over the lake basins, and only obstructed by the great islands of Ontario and Michigan, with beaches far higher than the now numerous valleys, radiating to the north, east, south and west. The margins by this shrinking Warren Water were constantly contracting, as shown by the beaches, but its full dimensions are not yet known.

Until these investigations are further extended, this chapter in the history of the lake regions cannot be completed. Its beginning was at the close of the drift episode of the Pleistocene period, and its dismemberment was the episode of the birth of Algonquin and Iroquois Bays, which afterwards became lakes. But whether this great sheet of water existed as an arm of the sea, or a glacial lake, may be questioned by the opposing schools. The absence of marine beaches seems to be an obstacle on one side. A sheet of water, at least six or seven hundred miles long and four hundred wide, with several, or many outlets upon its southern side, appears still more unfavorable to the supposition of an ice dam to the east, of more than 2,000 feet in thickness, beneath which a river as great as the St. Lawrence was flowing, and continuing for the centuries which carved out the terraces and beaches. Indeed, some of the sea cliffs of the highlands of the Ontario peninsula, as well as terraces and beaches indicate a long wave action. The arguments set forth, against the glacial character of the Iroquois and Algonquin Beaches, obtain with greater force when applied to those of the Warren Water. But let these reasons rest in abeyance, and let others enter the harvest field not circumscribed by disputed hypothesis.

ART. XXIII.—*Notes on Ferro-Goslarite, a new variety of Zinc Sulphate;* by H. A. WHEELER.

ASSOCIATED with the sphalerite in a zinc-mine at Webb City, Jasper Co., Mo., there occurs a new variety of goslarite, or hydrous sulphate of zinc, that contains about 5 per cent of ferrous sulphate. It appears as incrustations and in stalactitic form on the wall of a large body of zinc-blende, with which marcasite and galenite are associated. Its origin is due to the oxidation and leaching of the zinc and iron sulphides, and their subsequent crystallization as the solution slowly concentrated by atmospheric evaporation. The occurrence of goslarite in the drainage of the mines of that district is quite common, according to Dr. W. P. Jenney, and where the seepage through the ore-bodies is very slight, the normal white to colorless sulphate of zinc is occasionally found as an incrustation on the sides of the mine; but in this case, a double sulphate of zinc and iron is found in the ratio of 4·9 $FeSO_4$ to 55·2 $ZnSO_4$ or nearly as 1:11. Thus far it has been found in only one mine and in very small amounts, which is hardly surprising in a district that is usually seriously troubled with water, when the ready solubility of the mineral is considered.

The mineral occurs in mammillary and stalactitic incrustations, with a prismatic, radiating structure. It is subtransparent, and light yellow to brown in color. Luster, vitreous. Hardness, 2·5. Brittle. Readily soluble in water, and has a highly astringent taste. Readily loses its water on exposure to the air, turning to an opaque, yellow powder. Fuses with intumescence on charcoal, finally leaving an opaque, brown, infusible mass that is feebly magnetic; otherwise gives the usual zinc and iron reactions.

The analysis given below shows a very slight contamination (0·8 per cent) from associated clayey matter,

Zinc sulphate	55·2	per cent.
Ferrous sulphate	4·9	"
Water	39·0	"
Silica	0·4	"
Alumina	0·4	"
Total	99·9	per cent.

As the properties of the mineral correspond so closely to those of goslarite, differing only, as far as studied, in the occurrence of ferrous sulphate with the variation to be expected therefrom, I have given it the name of ferro-goslarite. I am indebted to Mr. Arthur Thacher, E. M., for calling my attention to it, who first noticed its occurrence at Webb City and placed some of the material at my disposal.

ART. XXIV.—*On the Composition of Pollucite and its Occurrence at Hebron, Maine;* by H. L. WELLS.

IT is a matter of great satisfaction to announce the discovery of pollucite in a new locality. This very interesting mineral has heretofore been found only on the Island of Elba and even there in very small quantities, so that it may be called a mineralogical rarity. Its composition, in being the only known mineral in which caesium is an essential constituent, adds greatly to its interest.

Before describing the American material, some account of the history of the mineral may be given. In 1846, Breithaupt described* two minerals from Elba, which he called Castor and Pollux from their great similarity in appearance. He distinguished them easily however by their difference in specific gravity. Castor is now considered to be identical with petalite, and it is a fact worthy of mention that the latter mineral is found at Peru, Maine, only a few miles from the new pollucite locality, a fact which points, perhaps, to a new association of "Castor and Pollux." Breithaupt's material was analyzed by Plattner,† but at that time caesium had not been discovered, so that he naturally mistook it for potassium. His results were as follows:

	1. Plattner.
SiO_2	46·200
Al_2O_3	16·394
Fe_2O_3	0·862
K_2O	16·506
Na_2O‡	10·470
H_2O	2·321
	92·753

Plattner sought in vain for an explanation of his low results, and, not having enough material to repeat his analysis, he published it as it was. The discrepancy remained unexplained until in 1864, eighteen years later and after Plattner's death, Pisani§ discovered caesium in the mineral. Pisani states that, if Plattner's analysis be re-calculated on the supposition that the caesium was weighed as platinichloride while the soda was calculated in the usual way from the weight of the mixed chlorides, that the results would correspond closely to his own

* Pogg. Ann., lxix, 439.
† Ibid., p. 446.
‡ With trace Li_2O.
§ C. R., lviii, 714

analysis. Brush afterwards published a re-calculation* on this assumption, which is given below under 1*a*. Since Plattner used 0·5 gram. of substance for his analysis, the footing still hardly does justice to his well-known skill as an analyst. I have therefore made a new re-calculation, given under 1*b*, assuming that Plattner's platinichlorides contained enough potassium to make an exact summation. This assumption is warranted to a certain extent by the fact that all analyses of pollucite since Plattner's give at least a trace of potash. This calculation of the potash cannot be considered very exact, but it is quite probable that a part of the excess shown by the other re-calculation was due to the presence of this substance.

1*a*.	Plattner, Re-calculated.		Ratio.	1*b*.	Plattner, Re-calculated.		Ratio.
Si_2O	46·20		·770 or 4·64	SiO_2	46·20		·770 or 4·64
Al_2O_3	16·39	·161	·166 or 1·00	Al_2O_3	16·39	·161	·166 or 1·
Fe_2O_3	0·86	·005		Fe_2O_3	0·86	·005	
Cs_2O	35·69	·127		Cs_2O	29·80	·106	
K_2O	----	----	·155 or 0·93	K_2O	2·71	·029	·163 or 0·98
Na_2O	1·72	·028		Na_2O	1·72	·028	
H_2O	2·32		·129 or 0·78	H_2O	2·32		·129 or 0·78
	103·18				100·00		

The analysis which Pisani made on his discovery of caesium in the mineral, is as follows:

2.	Pisani.		Ratio.	2*a*. Ratio with assumed correction. (Na_2O=2·17 per cent.)
SiO_2	44·03		·734 or 4·56	·734 or 4·56
Al_2O_3	15·97	·157	·161 or 1·00	·161 or 1·00
Fe_2O_3	0·68	.004		
CaO	0·68	·012		
Cs_2O†	34·07	·121	·196 or 1·22	·168 or 1·04
Na_2O†	3·88	·063		
H_2O	2·40		·133 or 0·83	·133 or 0·83
	101·71			

Pisani is very positive about the freedom of his caesia from any considerable amount of potash, and he determined the atomic weight of his alkali-metal in support of this; hence it is scarcely allowable to re-calculate his analysis, as has been done

* This Journal, II, xxxviii, 115. † With traces of K_2O and Li_2O.

in the case of Plattner's, with the assumption that the excess was due to the presence of potash. It is the author's opinion, from a consideration of one of Rammelsberg's analyses which will be mentioned later and of the analyses of the new material from Maine, that Pisani's excess was at least largely due to too much soda, either derived from glass vessels or from some other cause, hence a ratio is given under 2*a* above, after deducting 1·71 per cent of soda from the analysis. Pisani deduced from his analysis the oxygen ratio, $SiO_2 : Al_2(Fe_2)O_3 : Cs_2(Ca_1Na_2)O : H_2O = 15 : 5 : 2 : 2$. This ratio would be expressed by the very complicated formula, $45SiO_2 . 10Al_2O_3 . 12Cs_2O . 12H_2O$.

Pisani certainly left the question of the true composition of pollucite open to doubt, and in 1878 Rammelsberg published* a new analysis of the mineral with the view of clearing up the doubt. Rammelsberg's material was evidently not well adapted to the purpose of determining the composition of the mineral, for he first picked from it some pieces, "more or less translucent," and obtained from them, Al_2O_3 16·58, alkalies precipitated by platinic chloride 23·03, Na_2O 2·00, Li_2O 0·83; then he picked from the same material, some fragments which had a specific gravity of 2·868, the lowest number which has ever been given for the mineral, although Breithaupt gives the same number as the lowest of a series, and he made the following analysis from it:

3.

	Rammelsberg, First analysis.		Ratio.
SiO_2	[48·15]		[·802 or 5·01]
Al_2O_3	16·31		·160 or 1·00
Cs_2O	30·00	·106	
K_2O	0·47	·005	·151 or 0·94
Na_2O	2·48	·040	
H_2O	2·59		·144 or 0·90
	100·00		

On this single analysis, where an important constituent was determined by difference and where the material was of questionable purity, Rammelsberg obtains the formula which is now generally accepted for the mineral. The analysis corresponds to the formula $H_2R'_2Al_2(SiO_3)_5$; Rammelsberg includes the hydrogen in R′ and writes it $R'_4Al_2(SiO_3)_5$.

It may be inferred that Rammelsberg himself was not fully satisfied with his results, for about two years later, he published† an analysis of what he describes as the purest material.

* Berlin. Akad., 9, 1878.

† Berlin. Akad., 671, 1880.

This analysis is given below:

	4. Rammelsberg, New analysis. I.	II.	III.	Ratio from the mean of 4.		
SiO_2	46·48	----	----		·775 or 4·58 or 9·16	
Al_2O_3	----	17·24	----		·169 or 1·00 or 2·00	
Cs_2O	----	30·71	30·53	·109		
K_2O	----	0·78	0·41	·006	·151 or 0·89 or 1·78	3·30
Na_2O	----	2·31	2·19	·036		
H_2O	2·32	----	----		·129 or 0·76 or 1·52	

He does not publish any ratio with this analysis, but says: "*These results confirm the former.*" The emphasis is Rammelsberg's. It may be noticed, however, that this analysis corresponds very closely to the formula, $9SiO_2 . 2Al_2O_3 . 2R'_2O . 1\frac{1}{2}H_2O$, or, putting in H with R′, it corresponds very well with the metasilicate formula, $R'_6Al_4(SiO_3)_9$. Moreover the formulæ just mentioned correspond much better with the analyses of Plattner and Pisani than Rammelsberg's formula does. What the probable formula for pollucite is, will be discussed after giving the analysis of the Hebron mineral.

The locality, Hebron, from which the new material comes, furnished the lepidolite from which Allen* extracted a large quantity of caesium and rubidium, the material used by Johnson and Allen† in determining the atomic weight of caesium as now accepted. Hebron also furnished the remarkable beryl in which Penfield‡ found 2·92 per cent of caesium oxide. It might have been expected, therefore, that this locality would be likely to furnish pollucite; indeed, Professor Brush tells me that he has tested a large quantity of quartz fragments from the locality, hoping that some of them might be this mineral.

The specimens were found during the past summer by Mr. Loren B. Merrill, of Paris, Me., and a few pieces were sent by him for identification to Professor Brush, who very kindly gave them to the author for examination. Mr. Merrill has since very generously loaned us his whole stock of the mineral, amounting to more than half a kilogram, in order that a thorough examination might be made. The mineral is said by the discoverer to have been found in cavities.§ It was associ-

* This Jour., II, xxxiv, 367. † This Jour., II, xxxv, 94.
‡ This Jour., III, xxviii, 29.
§ Mr. Merrill says, in a letter received after this article was in print, that the pollucite was found in only two cavities. In one of these only two or three pieces were found, associated with large, etched quartz crystals. In the other cavity the main part of the mineral was found in a loose heap mixed with clay. This last cavity was open at the top, and was 3 feet wide 6 feet long and 18 inches deep.

ated with quartz, a crystal of which was in one case imbedded in the pollucite, also with psilomelane and with another mineral which proves to be a nearly colorless, brilliant caesium-beryl. The pollucite was in the form of irregular fragments, mostly between $\frac{1}{4}$ and 10 grams in weight, very similar to those figured by Breithaupt in his original description of the mineral from Elba. The substance of many of the fragments, such as were used for the analysis, was of the most perfect physical character, perfectly colorless and as brilliant and transparent as the finest glass.

Prof. S. L. Penfield has kindly made the following report of an optical examination of the substance :

"Refractive indices on a prism of 43°41′ :

$$n = 1\cdot5215 \text{ Li}$$
$$n = 1\cdot5247 \text{ Na}$$
$$n = 1\cdot5273 \text{ Tl}$$

"The mineral shows no double refraction, hence it is isometric. Under the microscope it is very free from inclusions. Some of the specimens show a series of holes, in parallel position, extending into the substance of the fragment at right-angles to its surface. These holes have rectangular cross-sections and they give to some of the specimens a sort of fibrous structure." Unfortunately, none of the fragments have any distinct crystalline faces.

In its pyrognostic properties, its luster and hardness and its lack of any apparent cleavage, it agrees exactly with the observations of Breithaupt, Plattner and the other observers in regard to the Elba mineral. It is completely, though slowly, decomposed by hydrochloric acid with the separation of pulverulent silica. This agrees with the observations of Plattner and Pisani, but not with the statements of Rammelsberg. The latter was doubtless deceived by the slowness of the action, for it takes several hours to decompose the finely pulverized mineral with moderately concentrated acid at the heat of the water-bath.

The specific gravity of the Hebron mineral was taken twice on each of two fragments; one gave 2·985 and 2·987, the other 2·976 and 2·977. It will be noticed that the Maine mineral is considerably heavier than that from Elba. Breithaupt gives 2·868, 2·876, 2·880 and 2·892; Pisani gives 2·901; Rammelsberg gives for the material used in his first analysis 2·868, and for the pure material used in his second, 2·885 to 2·896. All of this European material, except that used by Rammelsberg for his first analysis, is described by the various observers as being colorless and transparent. The indications are that the higher specific gravities represent the better material, and

the comparatively high specific gravity of the American mineral seems to point to still better quality if not to some difference in composition.

A single piece of the very best quality was selected for the chemical examination, while the water was determined in two other fragments also, because of the evident importance of the water in calculating the formula. Analyses I and II were first made, but, as they did not show a perfect agreement in the determinations of the alkalies, No. III was then made with the greatest care. This last is considered the best of the analyses and the ratio given is calculated from it, but it will be noticed that the other two analyses confirm this quite well and that they both point to the same formula with almost equal sharpness.

Water was determined by loss by ignition, as given in detail beyond; the "intense ignitions" were made in small platinum crucibles over a powerful blast-lamp flame, so that the heat obtained was very high. The material was not dried in any way before weighing. The mineral was decomposed by hydrochloric acid, and silica, alumina and lime were determined by the usual methods, care being taken to take account of the slight impurities in the silica and alumina. The alumina contained a very faint trace of iron, no more than might have been introduced by breaking the mineral up with steel cutters; no evidence could be found of the presence of other elements in the alumina. The identity of the lime was shown by the spectroscope.

The alkali-metals were weighed together as chlorides, then caesium and potassium were separated and weighed as platinichlorides; the alkali-chlorides in the latter were separated and weighed in order to calculate the proportion of caesia and potash. The potassium spectrum was detected from these last chlorides with considerable difficulty, while they showed no rubidium spectrum whatever. Lithium chloride was separated from sodium chloride, after the removal of the excess of platinum, by the method of Gooch, and the soda was calculated from the difference between the other chlorides and the total mixed chlorides, while in analysis III the sodium chloride was also weighed directly, giving a result which happened to be exactly identical with the indirect determination. This agreement of the direct with the indirect determination of the soda may be considered as an indication that the other alkalies were determined with reasonable accuracy. The lithium was identified with the spectroscope.

The following are the results of the analyses:

	Single piece.			Two separate pieces.	
	I.	II.	III.	IV.	V.
Weight of substance taken	0·6260	1·1291	0·9491	1·0205	1·4826
Loss by heating at 125°–130°	----	----	0·00	----	----
Loss by heating at 165°–170°	----	----	----	0·03	0·01
Loss by heating to red heat	1·49	----	1·50	1·56	1·50
Loss by intense ignition	0·04	----	----	0·02	0·03
H_2O	1·53	[1·53]	1·50	1·58*	1·53*
SiO_2	43·48	43·59	43·51		
Al_2O_3	16·41	16·39	16·30		
CaO	0·21	0·22	0·22		
Cs_2O	36·77	35·36	36·10		
K_2O	0·47	0·51	0·48		
Na_2O	1·72	2·03	1·68		
Li_2O	0·03	0·04	0·05		
	100·62	99·67	99·84		

The ratio calculated from No. III, and the calculated composition, giving the alkalies the same proportion as in the analysis, but omitting lime and lithia as insignificant, is given below:

Hebron Pollucite. Ratio from analysis III.

SiO_2		·725 or	4·53 or	9·06
Al_2O_3		·160	1·	2·
CaO	·004			
Cs_2O	·128			
K_2O	·005	·166	1·04	2·08
Na_2O	·027			
Li_2O	·002			
H_2O		·083	0·52	1·04

Calculated for $H_2R'_4Al_4(SiO_3)_9$ ($R'=\frac{128}{160}$ Cs, $\frac{5}{160}$ K, $\frac{27}{160}$ Na.)

SiO_2	43·55
Al_2O_3	16·45
Cs_2O	36·38
K_2O	0·48
Na_2O	1·69
H_2O	1·45
	100·00

The sharpness of the ratio and the agreement of the analysis with the calculated composition are all that could be desired. There can be no doubt, then, that the composition of the Hebron mineral is represented by the formula $9SiO_2 . 2Al_2O_3 . 2R'_2O . H_2O$ or $H_2R'_4Al_4(SiO_3)_9$. The theoretical composition for $H_2Cs_4Al_4(SiO_3)_9$, supposing no alkalies except Cs_2O to be present, is,

SiO_2	40·72
Al_2O_3	15·39
Cs_2O	42·53
H_2O	1·36
	100·00

A comparison of all the ratios given in this article, as shown in the following table, makes it probable that the new formula

* Not including, respectively, 0·03 and 0·01 per cent of water lost at 165°–170°.

can be assigned also to the Elba mineral. The ratios have been calculated with Al_2O_3 as unity because it shows less variation throughout the analyses than the other constituents.

	Ratios.			
	SiO_2 :	$Al_2O_3(Fe_2O_3)$:	R'_2O :	H_2O
Plattner's analysis as re-calculated by Brush	4·64 :	1·	: 0·93 :	0·78
Plattner's analysis newly re-calculated	4·64 :	1·	: 0·98 :	0·78
Pisani's analysis	4·56 :	1·	: 1·22 :	0·83
Pisani's analysis with assumed correction	4 56 :	1·	: 1·04 :	0·83
Rammelsberg's analysis on which he based his formula	[5·01]:	1·	: 0·94 :	0·90
Rammelsberg's later analysis	4·58 :	1·	: 0·89 :	0·76
Analysis of Hebron pollucite	4·53 :	1·	: 1·04 :	0·52
Proposed formula requires	4·50 :	1·	: 1·00 :	0·50
Rammelsberg's formula requires	5·00 :	1·	: 1·00 :	1·00
Or, as he writes the latter	5·00 :	1·	: 2·00	

Leaving out of consideration Rammelsberg's first analysis, there can be little doubt that the new formula expresses the composition of Elba pollucite as far as the first three members of the ratios are concerned, but the water is 0·8–0·9 per cent higher in the analyses of that material than the formula requires. A part of this excess may be accounted for by supposing it to take the place of any deficiency in the alkalies, as will be noticed especially in the last analysis of Rammelsberg; hence, since the small excess of water cannot be introduced into the formula without complicating it greatly and destroying the metasilicate ratio, it is probably best to consider it as accidental. The replacement of a small part of the alkalies by water in the Elba mineral would explain its lower specific gravity.

It is satisfactory to notice that the historical first analysis by Plattner confirms, in each of its re-calculated forms, the conclusions arrived at in this paper.

Sheffield Laboratory, New Haven, Conn.
January, 1891.

ART. XXV.—*The Volumetric Composition of Water;* by EDWARD W. MORLEY.

UNTIL recently, our knowledge of the volumetric composition of water depended on the results of Humboldt and Gay-Lussac. They presented their memoir to the Academy of Sciences at Paris. The memoir was printed in full in the Journal de Physique* and translated in Gilbert's Annalen der

* Vol. lx, p. 129.

Physik.* Chaptal and Berthollet made a report on the memoir to the Academy, which is contained in the Annales de Chimie et de Physique.† Humboldt and Gay-Lussac made twelve experiments with an excess of hydrogen, and twelve with an excess of oxygen. They determined the amount of nitrogen in their oxygen by absorption with an alkaline sulphide, and with this oxygen determined the amount of nitrogen in the hydrogen. The mean error of the measurement of the residue after explosion with an excess of hydrogen was one part in five hundred, and in the experiments with excess of oxygen, one part in two hundred and fifty. From the experiments with excess of hydrogen they deduce 1·9989 as the measure of the ratio sought; from the experiments with excess of oxygen, they infer that both series together justify the conclusion that one hundred volumes of oxygen combine with very nearly two hundred volumes of hydrogen. They do not compute the ratio from the experiments with excess of oxygen: it would be 1·982. Since I began experiments on the matter, Scott has published several statements of his results. In his first paper,‡ he gives the results of twenty-one experiments. He gives two sets of values of the ratio sought; one computed on the assumption that the impurities found in the residue after explosion were originally distributed proportionally between the two gases, and the other on the assumption that all the impurity was contained in the oxygen. From the whole twenty-one experiments, he gets the two values 1·9857 and 1·9941 respectively; excluding two experiments in which the impurity was very great, he gets 1·9897 and 1·9959; from the best four experiments he gets the values 1·9938 and 1·9964; from the six best, he gets the values 1·9938 and 1·9967. The mean error of a determination was one part in two hundred and fifty on the first assumption, and one part in five hundred on the second. Rejecting the two worst experiments, the mean errors become one part in five hundred and one part in seven hundred and fifty parts. He gives the value 1·994 as the most probable value of the ratio sought; but from a consideration of the same experiments, Young§ judges that the value of the ratio is between 1·996 and 1·998, and may perhaps be taken as 1·997.

In the autumn of 1887, Scott‖ stated that he had then made over thirty experiments, and gave the most probable value of the ratio as 1·996 to 1·997. In the spring of 1888, Scott¶ published four other experiments with a new and larger apparatus; their mean is 1·997; the gases used sometimes contained as

* Vol. xx, p. 38, 1805.
† Vol. liii, p. 239, 1805.
‡ Proceedings, R. S., vol. xlii, p. 398.
§ Nature, vol. xxxvii, p. 390, 1888.
‖ Br. Assoc. Trans., 1887, p. 668.
¶ Nature, vol. xxxvii, p. 439, 1888.

little impurity as one part in fifteen thousand. In the autumn of 1888, Scott* stated that the volume of hydrogen required seemed to decrease when it was evolved continuously from the same apparatus; and that the variation showed some impurity at present undetected. He published the results of four experiments giving values varying from 2·001 down to 1·995.

My own experiments on this matter are a part of one of my processes for determining the ratio of the atomic weights of oxygen and hydrogen. In this determination, the ratio of the densities of the two gases under ordinary conditions is one factor, and the ratio of their combining volumes under the same conditions is a second factor. Since it is difficult to free hydrogen from nitrogen, I hoped to obtain it free from every other impurity, and to determine the amount of nitrogen contained in it, so that I could compute a numerical correction to the observed density. I have now finished the determination of the combining volumes of the gases unless some as yet undetected error should necessitate further investigation. I have been able to reduce the mean error of a determination to less than one half of that which I ventured to predict early in the volumetric studies preliminary to the actual determinations.† As the degree of accuracy which I hope it will be found that I have attained is very considerably greater than in determinations of the same kind by others, I have thought it needful to give a somewhat minute account of the details of the work, in order that those interested in the matter may better judge what degree of confidence may fairly be reposed in the result, or may be in a position to suggest improvements or corrections needed in my processes. Though some parts of the work go back for many years, yet, thoroughly agreeing with the expression of Ostwald that he undertakes a heavy responsibility who publishes values of constants, I have made public no figures obtained till I have done the best that I know how to do.

Preparation of pure hydrogen.—The preparation of pure hydrogen has been difficult. I tried long to obtain it by the action of dilute acids on zinc. It is in this way not difficult to obtain the gas free from arsenic and sulphur (or chlorine), and easy to obtain it free from oxygen by passing the hydrogen over heated copper; but two difficulties remain, one of which is serious. The amount of hydrogen which can be obtained from a given weight of materials is not always enough to sweep out all the nitrogen present in the apparatus or contained in the liquids used and still leave much of the gas to be utilized. Perhaps, by constructing the apparatus so that it can be repeatedly exhausted, this difficulty could be overcome.

* Br. Assoc. Trans., 1888, p. 631.

† Am. Chem. Journal, vol. x, p. 23, 1888.

But a difficulty which I have not yet surmounted proceeds from impurities found in every sample of zinc which I have heretofore obtained. The metal contains gases which were absorbed by it during metallurgic processes; of such gases, carbon dioxide is but one; this could be easily removed, but there are present other gases which contain carbon; until they shall have been sufficiently investigated it is not certain whether they can be removed by absorption.

It is to be noted that this last difficulty is by no means removed by amalgamating the zinc, and using it as one pole of a voltaic element or of a decomposing cell. The best zinc I have found gave when so used hydrogen which after combustion in no very long time caused a precipitate in lime water. The gas also contained nitrogen which came from the zinc employed;* I therefore abandoned for the present the use of zinc. Dr. W. H. Burton kindly distilled in a vacuum for me some kilograms of so-called perfectly pure zinc; with which product I shall some time resume the preparation of pure hydrogen.

Having abandoned, perhaps too hastily, the attempt to get pure hydrogen from zinc, I resorted to electrolysis. The decomposition of an alkaline hydroxide seemed promising; by it one would expect to get nothing but hydrogen, oxygen, hydrogen dioxide and ozone. From the decomposition of absolutely pure potassium or sodium hydroxides, no doubt this pleasing ideal might be realized. But two decomposing cells which I constructed for the purpose and filled with so-called pure potassium hydroxide yielded hydrogen containing carbon. This might possibly come from organic matter adhering to the interior of the cells, although I was at that time especially on my guard against carbon; but it was more probable that it came from the simultaneous electrolysis of an alkaline carbonate. I therefore made a new decomposing cell most carefully of clean glass and platinum, cleaned it from organic matters derived from glass blowing manipulations by long immersion in chromic acid, but filled it with potassium hydroxide to which I purposely added potassium carbonate. The electrolysis of this solution yielded hydrogen which instantly clouded lime water on combustion. It was therefore plain that the alkaline solution submitted to electrolysis must not contain any carbonate. This might no doubt be attained by using barium hydroxide, either alone, or added to potassium hydroxide to remove carbon dioxide. But since the so-called pure potassium hydroxide is purified by solution in alcohol, it is by no means certain that it may not contain carbon other than that existing in an alkaline carbonate. The matter, therefore, began to

* Amer. Chem. Journal, vol. xii, p. 461, 1890.

assume such an aspect that I resorted to the use of sulphuric acid.

Decomposing cell for 25 *liters an hour.*—I have at command, through the courtesy of the East Cleveland Railroad Company, by day and night an electromotive force of five hundred volts. It was obviously proper to use the current from this source by passing it in succession through many small decomposing cells, rather than through one large cell. It was convenient to have at command a current of hydrogen up to twenty-five liters an hour. To obtain this from a single cell would require a current of some fifty amperes; consuming thirty-three horse power. But if a current of one-thirtieth this amount is passed through thirty cells in succession, the same amount of hydrogen is obtained from one horse-power. I therefore sealed thirty decomposing cells to two delivery tubes, so that when the electric current is passed through them, the hydrogen produced is all given off at one tube, and the oxygen at the other. These cells were made by an eminent firm in Germany; twenty-six of them, on treating them precisely as those of my own construction had been treated, cracked at the bottom of the U-tube, having been obviously bent at too low a temperature. After this dismal accident, I had myself to make the set of decomposing cells shown in fig. 1 at *aa*. Each of the six cells shown is the front one of a column of five which are fused into the transverse delivery tubes shown in section at *bb*. Six such columns are fused to the longitudinal delivery tubes. It is convenient to immerse the cells in water to keep them cool; it is therefore necessary to insulate each electrode in a glass tube as seen in the figure. The oxygen produced was led off to the tall cylinder seen to the left, containing a column of water such as to make the pressure on the escaping oxygen nearly equal to that on the hydrogen when it was permitted to escape at the end of the purifying train. This oxygen was sometimes utilized, as for oxidizing copper. The set of decomposing cells was supported in a copper trough for water for cooling. It was filled with distilled water containing one-sixth its volume of pure sulphuric acid which I distilled just before using it. The decomposing cells had a capacity of six liters; a little more than five liters dilute acid was put into them.

Purifying train.—At *cc* is an enlargement to prevent the passage of acid over into *d** when the current is rather rapid. *d* contains a fifty per cent solution of potassium hydroxide. *e* contains sulphuric acid for the preliminary drying of the

* The individual parts of the apparatus are drawn accurately to scale, as noted; but the connections between parts are represented more compactly than in the actual apparatus.

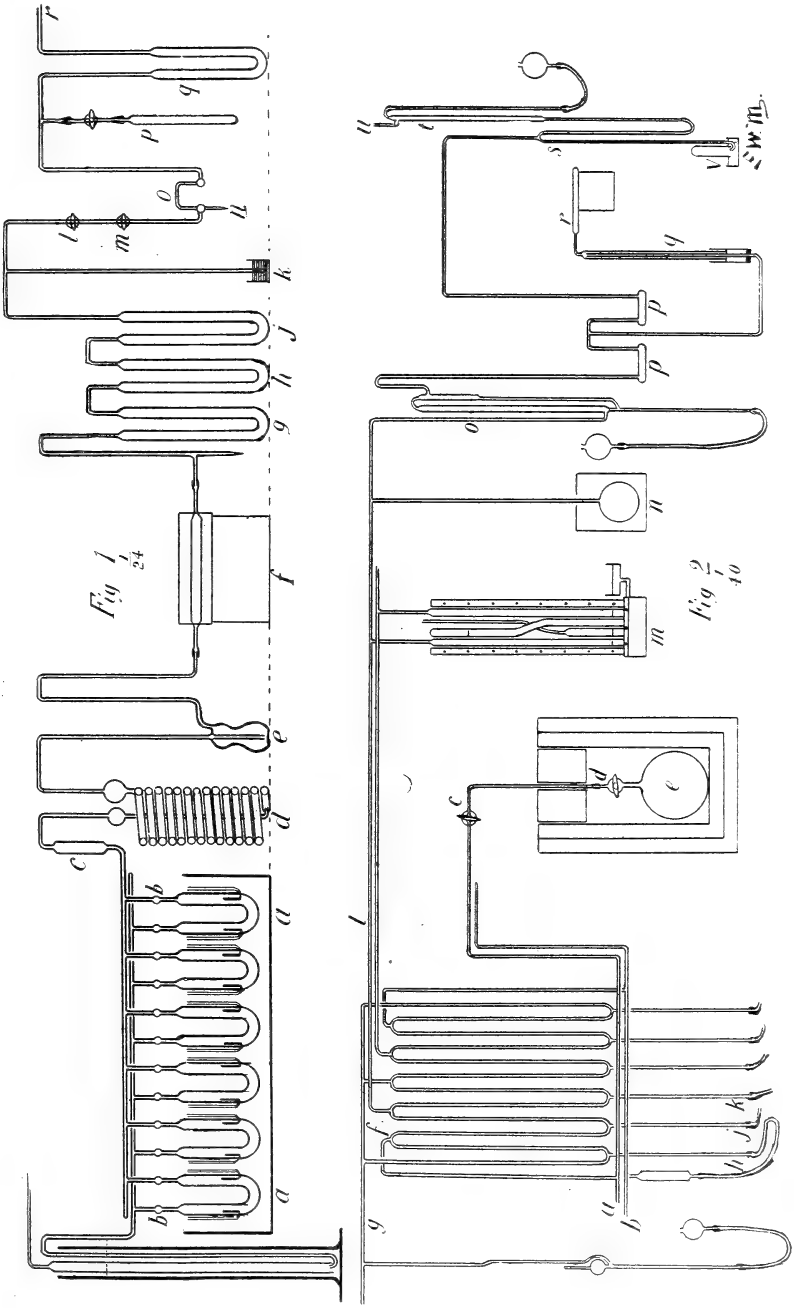


Fig 1
1/24
Fig 2
1/10
W.M.S.

gas. In the furnace at *f* is a tube filled with copper; this tube of hard glass is joined to the soft glass tubes of the rest of the apparatus by ground joints made tight with syrupy phosphoric acid. As this part of the apparatus was not exhausted, no difficulty was experienced in keeping the joints tight. At *g* is a tube containing glass beads and sulphuric acid; this (as well as the two following tubes) lay horizontally, so that the acid should remain well distributed throughout the beads. At *h* is a tube filled with powdered potassium hydroxide, and at *j* is a tube filled with glass wool and phosphorus pentoxide. At *k* is a vent through mercury; at *m* are two glass stop-cocks in succession, which have been lubricated with syrupy phosphoric acid. Their office is at present simply to regulate the flow of gas when the valve at *o* is opened.

At *o* is a valve consisting of glass tubes containing plugs of fusible metal. Two tubes which are perpendicular to the plane of the paper are seen in section; between them are placed several inverted U-tubes. Each one contains a plug of metal; when it is desired to admit hydrogen to the part of the apparatus to the right of the valve, one of the plugs is fused; when it is desired to close the valve, the glass tube is fused together. It may be noted that with a proper composition of the metal, these valves make a joint as tight as could be desired, and that there was no failure by the splitting of the glass tube. By having several of these tubes, it was possible to make and again to cut off the connection between the two parts of the apparatus as often as desired. Of course new tubes were put in before each experiment; in this way, air was admitted to the tube between the valves *o* and the stop-cock *m*, but air never was admitted into the part of the apparatus to the left of *m* except by fracture of the apparatus. To remove the air from the tube *mo*, a tube was provided as shown at *n*; from which hydrogen was permitted to escape for a long time before each experiment. When *n* was closed by fusion, one of the valves at *o* was opened and the connecting tube between *m* and *o* was exhausted by the pump which had exhausted the apparatus to the right of *o*. During this exhaustion, the two stop-cocks *m* had to withstand a difference of pressure equal to that of the atmosphere. This they could not do without permitting some leakage of hydrogen into the vacuum which was then producing to the right of *m*. This however, gave no difficulty, the exhaustion of the large volumes *e* and *n* had already been accomplished under the security of the perfectly tight metal valve, and then these were shut off, so that the leakage during the subsequent exhaustion of *m o p q r*, fig. 1, and *a c d*, fig. 2, was so slight that a vacuum of 1/50000 could be obtained in the small volume in question.

It was desirable that the hydrogen to be analyzed should not pass over any organic lubricant unless the lubricant were proved not to give up any carbon compound to the gas. Rather than investigate lubricants, I used syrupy phosphoric acid on the glass stop-cocks, and at first used no fusible metal valves, but prevented leakage while the exhaustion of the large volumes *e* and *n*, fig. 2, was in progress by maintaining a vacuum between the two stop-cocks by means of a second mercurial pump; but the manipulation was troublesome, and if the exhaustion was interrupted, the whole labor had to be recommenced.

In some of my experiments, I used hydrogen purified by the process suggested by Chirikoff,* namely, by utilizing the power of palladium to absorb hydrogen, and to give it off again at a higher temperature. In such experiments, a tube containing palladium was connected as shown at *p*, but a tube containing phosphorus pentoxide should have been shown between *o* and *p*, intended to arrest any aqueous vapor which might possibly be given off by the syrupy phosphoric acid at *m*. A second drying tube was placed at *q*, to answer the same purpose for the gas which should pass directly to *r* and the following parts of the apparatus.

The apparatus so far described serves to prepare pure hydrogen. In the case of all impurities to be feared, except oxygen and nitrogen, their absence is capable of proof by direct experiment, as sensitive reagents are applicable. It was not expected that hydrogen free from nitrogen could be prepared, and apparatus designed to measure the residual nitrogen was constructed, and will shortly be described. The only question remaining is as to the possible presence of oxygen after the hydrogen had passed the tube containing heated copper at *f*. To determine how much of a given substance fails to be absorbed by the best absorbent of the substance can be determined commonly only by indirect means which are of limited application. But in regard to the absorption of oxygen by hot copper, I think we can answer the question, and can perhaps also judge whether the presence of a great quantity of hydrogen will lessen the completeness of the absorption. If we pass a current of air containing a little aqueous vapor through a tube filled with phosphorus pentoxide, and also pass a current of air over heated copper in another tube, we can in some sort compare the activity of the two absorptions by observing how far each absorbent is visibly affected. I think we may judge that the copper is not enormously less active then the phosphorus pentoxide. Suppose the phosphorus pentoxide is a

* Journal Russ. Phys.-Chem. Soc., 1882, chemical part, p. 47.

hundred or a thousand times more active. Now, partly to obtain a solution of the present problem, I have determined* the amount of aqueous vapor which fails to be absorbed by a phosphorus pentoxide tube containing twenty-five cubic centimeters, when the rate of the current of gas is two liters an hour; the volume of the aqueous vapor left unabsorbed is not more than a thirty-millionth of that of the air. If then we make the surfaces exposed and the time of exposure comparable for the two absorbents, we may expect that the copper will permit not over a hundred or a thousand times this quantity to escape; by increasing the exposed surface, and the time of exposure, the absorption may be made as complete as we please, for at the temperature used, we have reason to believe that the reaction between copper and oxygen is not reversible. Considering also the action of hydrogen which accompanies the oxygen and is heated with it, it seems to me impossible to suppose that the gas of my experiments contained any such quantity of oxygen as 1/200000 its volume.

Purity of the hydrogen obtained.—Each time when a globe was filled with hydrogen for the determination of density, the amount of nitrogen in the hydrogen was determined. The first trial was made when a current of two or three liters an hour had been evolved for three days; the gas then contained ·00035 volumes of nitrogen. The amount became gradually less as the amount of hydrogen obtained from the apparatus increased. When the apparatus was not in use, it was always left closed by fusion against the entrance of nitrogen except by diffusion through the water in which the oxygen delivery tube ended. When about six hundred liters had been obtained, it became difficult to detect nitrogen; that is, its amount was less than one part in one hundred thousand. Sometimes concordant determinations of the amount of nitrogen showed only one part in two hundred thousand.

Apparatus for storing hydrogen for several experiments on the same sample.—Figure 2 shows the part of the apparatus serving for certain processes in the determination of the composition of water. In my methods, it was necessary to secure two considerable volumes of hydrogen which should be absolutely identical in composition, one to be weighed, and one to be analyzed. It was also necessary to preserve the second for several days, with no possibility of contamination by leakage or diffusion. Moreover, the sample for analysis must not come in contact with fatty lubricants, nor that for weighing in contact with mercury, from which it would take up mercury vapor affecting its weight. It would no doubt have been possible to have found a fatty lubricant which it would have

* This Journal, vol. xxxiv, p. 199, 1887.

been safe to use: but so many difficulties had to be surmounted that the pleasure of evading some was not to be disregarded, and I used no organic matter about the apparatus.

The tube *r* yielding pure hydrogen is continued in the tube *a* of fig. 2. And *a* leads directly to the stop-cock *c* just outside the calorimeter case containing *e* and to the stop-cock of the globe *e*. The manipulation of *c*, *d*, *e* will be described in a paper on the density of hydrogen and of oxygen; the gas in passing to *e* does not go near mercury. At *g* is seen a tube connected to a McLeod gauge, and leading to a Geissler air-pump having a capacity of 2·3 liters. This was kept in such condition that it was not difficult to exhaust the pressure gauge and the connecting tubes with a total volume of 700 cubic centimeters to one part in five million. It is therefore obvious that the amount of leakage through its ground joints which could take place during the exhaustion was negligible, and when the pump was not in use for exhaustion, it was shut off by a mercurial valve which was perfectly tight.

The vertical tubes seen immediately above the horizontal part of *a* form a six-way mercurial valve, of which three ways were used in the manipulation of hydrogen, and three in the manipulation of oxygen. When mercury is lowered in the tube *h*, a free passage exists between the Geissler pump with its McLeod gauge and the tube *a* leading to the valve at *o*, fig. 1, as well as to the weighing globe *e*, fig. 2. When the mercury is lowered in the tube *k*, there is a free passage from the pump to the mano-barometer and the store globe, *n*. And when the mercury is lowered in the tube *j*, there is a free passage between the tube *a* and the mano-barometer and the store globe. Of course this valve will saturate the hydrogen with mercurial vapor, but this part of the hydrogen is to be analyzed over mercury. Any hydrogen stored in the globe *n* is perfectly safe from contamination. The tubes were all most scrupulously cleaned, all joints were made by fusion, when possible, and the others are mercurial seals of sufficient depth; at the mercury six-way stop-cock, the hydrogen is shut off by at least thirty centimeters of mercury, at the mano-barometer, by thirty, and at the valve *o* by eighty centimeters. It was accordingly found that that hydrogen stored at in *n* contained no more nitrogen after keeping it for a month than on the day of its preparation.

Introducing hydrogen into the storage apparatus.—In filling *n* with hydrogen, *n* was exhausted to a twenty-five thousandth or a fifty thousandth part, and was then shut off from the pump. Then the tube between *d*, fig. 2, and *o*, fig. 1, was exhausted to a hundred thousandth. During these exhaustions, hydrogen had been escaping at *n*, fig. 1. The tube at *n* was then fused together, the stopcocks at *m* closed, and the valve *o*

opened. A good exhaustion was now produced back to the glass stop-cocks. The valve shutting off *n*, fig. 2, was now opened, as well as the stop-cock of the globe *e*, (but of this elsewhere), and hydrogen admitted to a tension of ten or twenty centimeters. Then the valve *o*, fig. 1, was closed, and a good exhaustion again produced in the whole apparatus, *m*, *n*, and *e*, fig. 2. The degree of exhaustion thought proper depended on circumstances. The pump was then shut off, the fusible metal valve opened, and hydrogen admitted till its pressure was a little greater than that of the atmosphere. The valve *j* being then closed, the hydrogen in *n* was ready for use.

The apparatus for preparing oxygen is not shown. Potassium chlorate was placed in a hard glass tube; this was fused to a similar tube containing finely divided silver and heated in a furnace. These two tubes were connected to the soft glass tubes of the remaining apparatus by a ground joint. First was a tube like *g* and *h*, fig. 1, with a fifty per cent solution of potassium hydrate, and then a similar tube with glass beads and sulphuric acid. Then followed a stop-cock used to keep the pressure in the apparatus so far nearly equal to that of the atmosphere. This stop-cock was lubricated with syrupy phosphoric acid, and was followed by a tube filled with phosphorus pentoxide, and ending at the tube *b*, fig. 2. This tube could be connected to the globe *e*, fig. 2, by making a fused joint at the proper place. It was also connected to the three mercurial valves and also to a system for storage of oxygen identical with that for hydrogen. The manipulation in filling this system with oxygen was much like that for filling with hydrogen.

Apparatus for extracting hydrogen and oxygen from the stores, and for preparing to determine residual nitrogen in hydrogen.—At *o*, fig. 2, is a mercurial valve which can be opened under difference of pressure. Those at the left of this figure can be opened only when the two pressures are equal. It also permits some regulation of the rate of flow. The descending tube which is connected directly to *n* contains a part so narrow that only a certain amount of gas can pass in a minute; the amount is calculated according to the size of the wider tube next following. Suppose this tube and those following to the right to be vacuous; when the mercury in the valve *o* is lowered so as to uncover the end of the descending tube where it enters the wider tube, gas will bubble up through the mercury which stands in the wide tube, and the rate can be adjusted by altering the level of the mercury. When the flow is rather rapid, the bubbles burst with such force as to throw some mercury over into the short wide tube at the right, whence it flows back by the tube provided for the purpose. By the use of this valve, it is possible to exhaust everything to the right of *o*, and then to introduce any required volume of

gas from the store in *n*. At *p* are two drying tubes intended simply to prevent aqueous vapor produced at *r* from entering *o* or *s*, and interfering with their action. At *s* is a Sprengel pump. The mercury which operates it first falls through the tube *t*, kept exhausted by a Toepler pump fused to *u* This trap is made long as shown so that even when the gas in *p*, *q*, *r* is at atmospheric pressure, mercury falling into *t* has still to pass through many centimeters of vacuum. At *v* is the jar in which the gas is transferred to the measuring apparatus. It is plain that, disregarding for the moment the apparatus *r*, we can, on opening the valve *o*, transfer gas from the store in *n* to the jar at *v*. But the apparatus at *r* has sometimes to perform an office which has made it possible to obtain from impure gases results as accurate as from pure gases. It will be recalled that Humboldt and Gay-Lussac obtained, although they worked with very impure gases, results whose mean errors are comparable with those of Scott, whose gases were far purer. This was owing to the fact that they devised means for measuring the impurities of one gas by some process other than the eudiometric explosions which determine the total nitrogen in both gases, and also the volume of the gas which has disappeared in the explosion. If Scott had succeeded in refining on the methods of Humboldt and Gay-Lussac in this respect as much as in his methods of preparing and measuring the gases, he might well have attained a degree of accuracy satisfactory to himself and answering the present demands of science. The apparatus *r* was designed to make possible the determination of the nitrogen contained in the hydrogen used. It consists of a hard glass tube filled with copper oxide, and united to the rest of the apparatus by means of a mercurial seal. The apparatus to the right of *n* was duplicated for oxygen, except that the tube *r* contained copper instead of the oxide, and no drying tubes *pp* were needed.

To get copper oxide which could be heated in a vacuum without giving off gas cost much trouble. Electrotype copper was oxidized in a current of oxygen; but when it was heated in a vacuum, it gave off a gas for a long time. In some cases, heating for several days answered the purpose; but some samples had to be rejected and the heating recommenced with a new sample. The gas given off was mostly absorbed by potassium hydrate, but as yet has not been further studied.

The mano-barometer *m* served partly in preparing for weighing the gas in the globe *e*, and partly in preparing for determining the amount of nitrogen in the hydrogen by means of the apparatus *r*. For the last purpose, an accuracy permitting readings to a thousandth of an atmosphere was sufficient; the apparatus will therefore not be described at present.

[To be continued.]

ART. XXVI.—*On the Intensity of Sound: A Reply to a Critic;* by CHARLES K. WEAD.

SEVERAL years ago I published in this Journal* some results of experimental work on the sounds from tuning forks. The final results as given then in Table VI, col. 6, showed results agreeing far better than one might expect who knew the difficulties, both experimental and theoretical, inherent in the problem.

The want of agreement, however, was great enough to attract the attention of Professor A. Stefanini, who, without repeating the experiments, has attempted to dragoon the figures into line by mathematical processes. An abstract† of his paper indicates a total misapprehension of the problem, and the original‡ (only recently accessible in this country) confirms this opinion of his work.

The critic first verifies my formula (5) for the potential energy of a bent fork, and then determines its mean kinetic energy during a vibration; by a laborious process he finds this to be half of the potential energy at the extreme of vibration —a conclusion that is one of the common-places of the theory of simple harmonic motion. But having obtained this formula he inserts the numbers given in my Table VI, cols. 2 or 3, then divides by the surface of the hemisphere, whose radius is 200 ft.; as the quotients for the different forks agree more closely than my results for S in col. 6, he thinks he is justified in considering that his method of discussing the observations is the better one.

Other attempts lead to similar conclusions and are based on the same utterly untenable premises. The critic considers the energy in the fork at any instant, and assumes tacitly that the sound given out is closely proportional to the energy: any one who has ever touched the stem of a vibrating fork to a sounding board, or held the fork before a suitable resonator, should appreciate readily the fact that it is *not the amount of energy in the fork* that is to be thought of in considering the intensity of the sound, *but the rate at which energy is given up* to the air. On this point text books are misleading when they say the loudness of sound is proportional to the square of the amplitude of vibration of the sounding body.

No matter how much energy the body may have, it is only the small fraction being given off at any instant that can cause the sensation of sound—and indeed only a part of this is effec-

* This Journal, III, xxvi, p. 177, 1883.
† Beibl. Ann. Phys. Chem., xiii, 636, 1889.
‡ Atti della R. Acc. di Lucca, xxv, 239–262, 1888.

tive in producing sound. Yet it is often assumed that the effective part of this fraction is a constant fraction of the total energy, for all amplitudes of vibration. The critic, I think, did this, as I can find no other possible explanation of the mistake he has made; but such an assumption is pure guess-work.

In the paper referred to, a considerable part of the work reported bore on the determination of the rate of loss of energy; it was found for example that, with Ut_3 fork at its maximum amplitude, it lost energy at a rate that would, if it had been continued uniform, have exhausted the supply in $4\frac{1}{2}$ sec.; but when the amplitude was very small, the rate too was reduced, and the corresponding time was 15 sec.

Stefanini, in a later paper,* criticises the form in which I write the exponent expressing the damping effect, viz:

$$\varkappa t = \left(a + b\,\frac{z' + z''}{2}\right)t$$

Where z' and z'' are the amplitudes at the beginning and end of the time t. He prefers to write it at^{m}; he finds for several forks, whose vibrations he photographed, that m was tolerably constant for each fork; for different forks it varied between 0·84 and 0·94. An important difference between the two formulas is that according to Stefanini's, the amplitudes at the end of successive equal times should be in a geometric series, or if the ratio of amplitudes is constant the intervals are constant; according to my formula in the last case, the intervals will increase as the amplitude diminishes. Stefanini used long thin forks intended for producing Lissajous's curves. From one of his tables (Tab. IX, p. 330 for Sol,) we deduce the following:

Time, arbitrary units	0	10	20	30	40	50	60
Interval		10	10	10	10	10	10
Amplitude on photograph,	48·3	32·3	22·8	16·35	12·2	9·2	6·6
Ratio		1·50	1·41	1·39	1·34	1·33	1·39

My Table II, p. 182, gives for Sol_3 the following ratios equal 2.

Amplitudes in div.	10–5;	8–4;	6–3;	4–2.
Intervals, sec.	4·70	5·34	6·31	8·17

Evidently the new formula does not fit any of the experiments exactly; like mine, it is only empirical, not rational; every experimenter must determine the formula that best fits his own conditions of working.

In this second and longer paper the author attempts to determine experimentally by forks whether the intensity of sound

* Beiblätter, xiii, 871. Atti, xxv, 307–400.

is to be measured by the energy or the momentum of the sounding body. Here unfortunately he falls into the old error, and tacitly assumes that the movement of the air corresponds exactly with that of the fork.

On this perplexing subject of the measure of a sound-sensation, most methods of experimenting are very faulty, as the following considerations will show:

First. When the experiment is to determine either the *minimum audible* or the equality of two sounds, if the sensations be the same, the causes must be the same; these causes are the movements of the particles of air near the ear, and the movements therefore being the same, their measure, whether as energy or momentum, must be the same. No discrimination then between rival theories can be made by the method of equal sounds.

Second. It is tacitly assumed in most of the experiments that I know of, whether by dropping balls or hammers, or by telephonic arrangements of various kinds, that the efficiency of the apparatus is substantially the same under all conditions, and in none has it been determined. Any one familiar with modern mechanical measures knows how much attention is given to determining under all the varying practical conditions the efficiency of electric, thermal and other machinery. But such laborious work as that of Vierordt and his followers seems much like trying to determine the laws of vision by first producing equality of illumination between a tiny incandescent lamp supplied with current from a toy boiler, engine and dynamo, and a distant powerful arc lamp with its boiler, engine and dynamo supplying it with many horse power, and then dividing the mechanical equivalent of the fuel used in each apparatus by the square of the respective distance from the eye or screen. Such a method might give the ratio of the efficiencies, but not anything of much value regarding the laws of vision. Every one knows that a ball falling on a metal plate will cause a louder sound than when falling on cloth; that is, the efficiency of the first as a sound-producing mechanism is much greater than the second; presumably if any other condition were changed, height of fall, weight of ball, material, etc., the efficiency would be changed; but experiments have been heaped up on the tacit but improbable assumption that it is not changed.

In conclusion, I desire to point out that my determinations for S, the energy per sq. c.m. per sec. at the limit of hearing, must be taken as outside values; they must be multiplied by the efficiency of the apparatus as a sound-producer; certain experiments have led me to infer that for the Ut_3 fork the efficiency was about 7 per cent, as stated in the original paper;

but this number is by no means certain, nor is it probably the same for all the forks; while the determination of its exact amount is doubtless difficult, I believe it will yet be made with fair accuracy.

Attention is asked to a few corrections noted below.

ERRATA.

To vol. xxvi, Sept., 1883, p. 179, line 1, for $2Vh$ read $2V_h$.

Page 181, equation (12), for p_2, read p^2.

Page 185, line 14, read mean velocity of the end of the prong.

Page 185, line 23, omit the exponent of l.

Page 187, Table V, column 6, footing, for 2·5, read 1·3; column 8, for Sol_4, read 1·26 and 1·33, mean 1·3.

Page 188, Table VI, column 5, 6, Ut_4, read 2550 and 1100; Table VI, line Sol_4, read 1.3; 127; ·29; 3680; 1590; 200.

Page 189, near close, read The smallest value of x to be obtained from Table VI, is (21×10^{-8} cm. for Ut_4 corrected) 9×10^{-8} cm. for Ut_5; from Allard's formula for $n=1024$ we get 21×10^{-8} cm.

Art. XXVII.—*The Fireball in Raphael's Madonna di Foligno*; by H. A. Newton.

In a recent *Notice from the Lick Observatory*,* Director Holden called attention to the fireball which Raphael painted in his picture, the Madonna di Foligno. Any facts relating to such a representation in such a picture cannot fail to be of general interest.

Among the Italian pictures in the Yale School of Fine Arts is a copy of this painting by Terry, and the copy is of such excellence that it has been hung in a prominent place in a collection consisting otherwise of original Italian works. In the picture the Virgin is in the clouds, and underneath the clouds, is a landscape with buildings. Upon the face of the sky and landscape is a rainbow, so placed as to suggest that the clouds under the Virgin's feet were resting upon the bow. Under the bow is a fireball of a tolerably brilliant red color. It is rounded in front and tapers somewhat behind. Slightly separated from the ball is a long reddish cloud curving back across the sky along the path which the fireball has described. This ball and cloud have sometimes been taken for a bomb and its track. The likeness of the representation to the usual pictures of bright fireballs and their trains, and the want of likeness to a bomb and its train are manifest upon the most casual examination. I feel sure that Raphael did not mean to depict a bombshell.

The introduction of a rainbow in a painting of the Madonna is not unique, and it may safely be assumed that its use is sym-

* Publications of the Astronomical Society of the Pacific, vol. ii, p. 19.

bolic, and that the bow is not a mere ornament of the landscape. In fact, if this last purpose had been the ruling one, we ought to have had a more natural representation of the rainbow, at least one more natural than that given in the copy. Moreover, since the painter placed a fireball and its train in close connection with the bow we are naturally led to ask what is the significance of such an unusual addition to the picture.

The picture was painted, it is said, in the year 1511 or 1512 for Sigismondo dei Conti da Foligno, private secretary of Pope Julius II. In the foreground is the figure of Sigismondo kneeling. Sigismondo died on the 18th of February, 1512. He had been made *Segretario domestico* to the Pope in 1503, and in his old age is said also to have been made prefect of the *reverenda fabbrica di San Pietro*, to which he bequeathed a considerable fortune. In this office he must have come into relations with Raphael after the latter came to Rome in 1508, and shortly before his own death Sigismondo ordered the painting of the famous picture. Tradition says that it was made in fulfilment of a vow, but I am not aware of any historic basis for the tradition. It is not improbable that the fireball first suggested the idea that the picture was a votive offering. It is not unlikely, also, that the picture was actually painted after the death of the secretary.

On the 4th of September, 1511, in the second hour of the night, there fell on the banks of the Adda near Crema, some leagues southeast of Milan, a number of stones. The following are accounts of this fall:

1. From the manuscript diary of a shoemaker, Gioanni Andrea da Prato, who resided in Milan, Amoretti* quotes the following entry made contemporary with the stonefall. The manuscript was in the Ambrosian Library in Milan.

"Ma prima che avanti col calamo scorra, dirò siccome il giorno quattro di settembre a ore due di notte, e anche alle sette apparve in aere in Milano un tale splendore di corrente fuoco, che parea refarsi il giorno; e da alcuni entro vi fu veduta una similitudine d'una grossa testa; il che diede alla città gran maraviglia e spavento; e il simile ancora accadette la notte seguente alle nove ore; poi dopo pochi giorni ultra il fiume Adda cascarono dal cielo molte prede (pietre) le quali raccolte furono nel Cremasco de libbre undici, e de libbre octo di colore simile a pietra arsa."

2. Bigot de Morogues† quotes from Père Bonaventure de Saint-Amable‡ this account:

* Opusculi Scelti, t. 22, p. 261, note; see also, Chladni, Feuer-Meteore, Wien, 1819, p. 210.

† Mémoire historique et physique sur les chutes des Pierres, etc., Orléans, 1812. p. 66.

‡ Annales du Limousin, vol. iii, p. 746.

"Le 4 septembre 1511, à Crême, en Lombardie, pendant un orage épouvantable, il tomba dans la plaine des pierres d'une grosseur considérable: six de ces pierres pesoient cent livres. On en porta une à Milan, qui pesoient cent dix livres. Leur odeur étoit semblable à celle du soufre. Des oiseaux furent tués en l'air, des brebis dans les champs, et des poissons dans l'eau."

3. Cardanus in a treatise *De rerum varietate** says:

"Vidimus anno MDX cum cecidissent e coelo lapides circiter MCC in agrum fluvio Abduæ conterminum, ex his unum CXX pondo, alium sexagita delati fuerunt ad reges Gallorum satrapas pro miraculo, plurimi; colos ferrugineus, durities eximia, odor sulphureus; praecesserat in coelo ignis ingens hora tertia: decidentium lapidum strepitus hora quinta exauditus. Ut mirum sit horis duabus tantam molem in äere sustineri potuisse. Intra viginti menses pulsi Galli. Triennio post reuersi, varia prius fortuna, inde iterum pulsi, ad excidium profligati. Urbs nostra in cujus finibus ceciderant lapides, vectigalibus, incendio, fame, obsidione, peste nunquam alias vexata grauius."

4. Lubienietski† quotes from Keckermann's *Syst. Phys.*, l. 6, c. 5, p. 890, as follows:—

"1511. Suessanus Scaligeri praeceptor commemorat, anno 1511, in Lombardia cometam instar ignei pavonis per äera volitasse, e quo, cum evanuisset, tres lapides sulphurei deciderint, horum primus 160 libras, alter 60 libras, tertius 20 libras pondere aequavit."

Several other accounts are quoted, or referred to, by Chladni, some of which are apparently repetitions of one or other of the above. Cardanus wrote his account when he was well advanced in years, and the stonefall occurred when he was ten years old and living at Pavia near the place of fall. He is not a careful writer, and his story instead of being treated as that of an eye witness should be looked at as the rehearsal of what Cardanus had heard people say in his childhood. It well expresses the fears then so common which large meteors and comets caused to men, and the belief that they were omens of terrible significance. His date is evidently in error. We may well question nearly all the details of all the accounts, but that many stones fell and some were carried to Milan and other cities, can hardly be doubted. It is so far as I know the only detonating meteor falling in Italy during several years preceding 1512 of which an account has been preserved. I believe that Raphael meant to represent this Crema aerolite in his painting of the Foligno Madonna.

* Reprinted in his works, see vol. iii, p. 278, Lyons, 1663.
† Theatrum Cometicum, vol. ii, p. 320.

What men thought of such phenomena was shown on the occasion of the fall of the Ensisheim stone 19 years earlier. This fell near the lines separating the contending French and Imperial forces. Maximilian soon after the fall had the stone brought up to the castle and he held a council of state to consider what the stonefall meant. Sebastian Brant, in a poem describing the fall speaks of the terror it caused to the Burgundians and French. Eleven years later, that is, in 1503, Maximilian in a proclamation appealing for aid against the Turks includes the Ensisheim stonefall among other indications of divine favor. It is natural, therefore, to inquire whether the course of political events in Italy in the latter part of the year 1511 and the earlier part of 1512 were such as to give the Crema stonefall in the minds of men special significance.

In the summer of 1511 the French and their allies were waging war with the Pope and were in possession of Genoa, Ferrara, Milan and the neighboring regions of Lombardy. They captured Bologna May 23, 1511. The Pope went to Rome June 27. In July he succeeded in forming a secret league with England, Spain and Venice to attack France. On the 17th of August the Pope was taken seriously ill, became unconscious on the 21st, and recovered consciousness on the 22nd. On the 1st of September the schismatic council at Pisa was organized. The Crema stones fell into the French territory Sept. 4th. The league between Spain, Venice, and the Pope was published Oct. 5th, and in November, England, and subsequently Maximilian joined the League. For a time success was with the French. On the 11th of April, 1512, the battle of Ravenna was lost by the papal forces and the Roman territory was seriously threatened. But in spite of such temporary success the French were forced to withdraw in June altogether from Milan and northern Italy. What would be more natural to Raphael under such circumstances than to unite in the altarpiece that he was painting the fireball with the rainbow in order to symbolize at once Divine reconciliation and assistance?

So far as I know no specimens of the Crema aerolites have been preserved. The accounts say nothing about the direction of motion of the fireball. It seems more probable, however, that the motion was from the South or West than from the North or East. The earth's quit was then about S. 35° W., 15° or 20° high. I have elsewhere shown that aerolites in general follow the earth in its orbit, and this makes a motion of this stone from the S. or W. quite probable. If it was moving from the East of South it would be more strikingly visible in Rome, and its appearance in Raphael's painting may be due to a brilliant course across the Roman skies.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *On the Dead Space in Chemical Reactions.*—In 1886, Liebreich called attention to the fact that in certain parts of a liquid in which a slow chemical reaction is taking place, either no change at all occurs or the change, if it take place, is diminished or retarded. This portion of the liquid in which the reaction is thus modified, he terms the "dead space." In the present paper, he gives the result of experiments made to determine the cause of this phenomenon. In studying it, he finds the most satisfactory reactions to be (1) the separation of chloroform by the action of sodium carbonate upon chloral, and (2) the separation of iodine by the action of sulphurous acid upon iodic acid; the extent of the reaction being easily distinguished in the first case by the turbidity given by the chloroform and in the second by the color of the iodine. The dead space appears at the free surface of the liquid and is easily visible to the naked eye. In narrow spaces, such as capillary tubes for example, the reaction is either greatly retarded or entirely prevented, as is clearly seen when iodic and sulphurous acids, mixed with starch solution, are placed in such tubes. When the tube is somewhat wider, the reaction takes place only along the axis, a thin thread of blue being apparent there. In the paper forty figures are given to show the character of the dead space in vessels of various sizes and shapes. As to the cause of the phenomenon, the author proves that the dead space at the free surface of the liquid is not due to evaporation. He considers that the physical influence of the walls of the vessel and the surface-tension of the liquid play an essential part in producing the dead space, there being developed by these actions a certain viscosity in the region where it exists, which hinders the reaction. The fact that the extent of the dead space diminishes with rise of temperature, is in favor of this view.—*Zeitschr. Physikal. Chem.*, v, 529; *J. Ch. Soc.*, lviii, 1207, Nov., 1890.

G. F. B.

2. *New Principle of Determining Molecular Masses.*—According to van't Hoff and Tammann, isosmotic solutions have equal vapor-pressures. So that, regarding the process of solution as equivalent to that of evaporation, the pressures of different solutions toward any special solvent, may be assumed subject to the same law. Consequently, if two isosmotic aqueous solutions be shaken with a given liquid, say carbon disulphide, this liquid will remove from each, equal quantities of water. If however, the osmotic pressure is different for the two aqueous solutions, that solution which has the lower osmotic pressure will lose more water than the other. The osmotic pressure of a solution, however, is a function of the character and quantity of the dissolved salt; and hence the quantity of water given up will also be a

function of the dissolved salt. NERNST has now pointed out that since the osmotic pressure is also a function of the molecular mass of the dissolved substance, a relation must exist between this molecular mass and the quantity of the solvent which will be dissolved out of the solution by a second liquid. Now, theory indicates that the relative decrease in solubility toward a second liquid which a solvent undergoes, owing to the addition of some foreign substance is represented by the ratio of the number of molecules of the dissolved foreign substance to the number of molecules of the solvent. Hence, if n foreign molecules be dissolved in 100 molecules of the solvent, and if a be the solubility of the pure solvent and a' that of the solution, $(a-a')/a'=n/100$. The correctness of this conclusion the author has proved experimentally, using solutions of various substances in valeric acid and in ether, the second liquid being water. If therefore, x grams of a substance whose molecular mass is M, be dissolved in 100 gram-molecules of the solvent, $n=x/\mathrm{M}$; and we have a means of determining the molecular mass of the dissolved substance simply by ascertaining the solubility of its solution in some second solvent. NERNST also proposes a new use of the freezing point apparatus for determining molecular mass. If a mixture of two liquids, such as ether and water for example be cooled to a low temperature, the water will begin to freeze; and this will take place at a temperature below zero, depending on the amount of ether dissolved. If now a third substance be dissolved in the ether, this substance not being soluble in water, it is evident that the solubility of the ether in the water will be lessened and the freezing point of the aqueous solution will be raised. So that calling t_0 the freezing point of a solution of ether alone in water, and t the freezing point after the addition of m grams of a substance of molecular mass M to 100 grams of the ether, $t/(t_0-t)=74\,m/100\,\mathrm{M}$. For example, 2·04 grams benzene were dissolved in 100 grams of ether and raised the freezing point 0·08° (corrected). Calling E the "molecular depression" for ether alone which is 3·06, and t' the corrected rise produced by the dissolved substance, the above expression reduces to $\mathrm{M}=\mathrm{E}m/t'$. Substituting the above numerical values, $\mathrm{M}=(3{\cdot}06\times2{\cdot}04)\div0{\cdot}08=78{\cdot}03$, the calculated molecular mass of benzene being 78. Using ethyl acetate as the solvent, benzene gave values from 75 to 82, naphthalene from 123 to 143, xylene from 101 to 118, toluene from 93 to 100, chloroform from 113 to 137 and phenyl benzoate from 222 to 255.—*Zeitschr. physikal. Chem.*, vi, 16; *J. Chem. Soc.*, lviii, 1368, Dec., 1890. G. F. B.

3. *On the Occurrence of free Fluorine in Fluorite.*—Certain varieties of fluor spar are known to emit a peculiar odor when struck, which odor has been variously explained by different chemists. Herrgott supposed the odor to be due to fluorine, Schaffhäutl to hypochlorous acid, Schrötter to ozone, Schönbein to antozone (given the name antozonite to a variety of fluorite which emitted a very strong odor on fracture), Wyrouboff to a hydro-

carbon and Loew to fluorine from dissociated cerium fluoride. BECQUEREL and MOISSAN have examined the fluorite of Quincié near Villefranche, which is markedly odorous; and they find that a gas is contained within this mineral, which can be seen to escape on breaking it under the microscope. On trituration this substance evolves ozone, sets chlorine free from chlorides, produces silicon fluoride on heating with silicon and gives hydrogen fluoride with water. All these results seem to indicate that the gas enclosed in this variety of fluorite contains a small quantity of free fluorine.—*C. R.*, cxi, 669; *Ber. Berl. Chem. Ges.*, xxiv, (Ref.) 4, January, 1891. G. F. B.

4. *On the Chemical condition of Iodine in its Solutions.*—GAUTIER and CHARPY have observed a remarkable relation between the color of iodine solutions and the character of the iodides formed by the iodine which they contain. Thus solutions in alcohol, ether, acetone, etc., are reddish-brown in color, while solutions in carbon disulphide and chloroform are violet. If mercury containing dissolved lead be agitated with the brown solution, a yellow precipitate of lead iodide is produced so long as lead remains in the mercury or iodine in the solution; minute traces of lead only being required to show it. If, however, the experiment be repeated with the violet solution a green precipitate of mercurous iodide results; and this equally whether the mercury be pure or whether it contains so much lead as to be pasty. With solutions having colors lying between these extremes, precipitates are obtained passing from yellow to green in the same proportion as the solution passes from brown to violet. A closer investigation seems to show that the iodine in the violet solutions combines directly with mercury to form the green iodide, even in presence of an excess of iodine; while the brown solutions give mercuric iodide which dissolves in the solvent (HgI_2 being soluble to the extent of 0·00842 parts in alcohol and only 0·00280 in carbon disulphide at 15°), and which facilitates the formation of the lead iodide; mercurous iodide not appearing until no more free iodine exists in the solution. The authors attribute this dissimilar behavior of iodine solutions to the supposed fact that the violet solutions contain iodine molecules of simpler constitution than do the brown solutions; a relation evidently existing between the color of the solutions and their molecular constitution.—*C. R.*, cxi, 645; *Ber. Berl. Chem. Ges.*, xxiii, Ref. 757, January, 1891. G. F. B.

5. *On the Properties of Carbon produced from Cyanogen.*—P. and L. SCHÜTZENBERGER have examined the carbon which is obtained on passing cyanogen gas through a porcelain tube heated to a temperature near softening. It formed a dense polished layer on the walls of the tube, resembling graphite. On putting into the tube a boat of retort carbon covered with cryolite, however, the decomposition takes place at a cherry-red heat; the tube becoming gradually filled with a blackish-green deposited carbon (A) consisting of a fibrous elastic mass, the fibers being felted

together and more compact on the edges. If a rod of aluminum be placed in the boat, a felted but non-elastic mass of carbon is deposited which can be kneaded and can be compressed into a mass like graphite (B). The variety (A) was treated with fuming nitric acid and potassium chlorate for 24 hours at 20° to 25°. A dark chestnut-brown powder remained undissolved, having the composition $C_{11}H_4O_5$. Further heating with the oxidizing mixture to 50°–60°, converted it into a bright brown-yellow powder, $C_{11}H_6O_6$, burning energetically when heated. Substances essentially similar were obtained from (B). It would appear that this carbon is not identical with either of the three varieties examined by Berthelot, although it resembles somewhat his "electric graphite." This latter, however, gives on oxidation a dark brown powder, which leaves on ignition a granular heavy residue; while the cyanogen carbon gives a bright brownish yellow oxidation product, yielding on ignition a fine light powder. From retort-carbon, however, the authors obtained the bright brownish yellow oxidation product; and they propose for such substances the name "carboxydhydrates.—*C. R.*, cxi, 774; *Ber. Berl. Chem. Ges.*, xxiv, Ref. 2, January, 1891. G. F. B.

6. *Principles of General Organic Chemistry;* by Prof. E. HJELT.—Translated by J. Bishop Tingle, Ph.D., F.C.S. 12mo, pp. x, 220. London, 1890. (Longmans). This little volume treats of the philosophy of organic chemistry. Ordinary text-books, devoted to the description of organic compounds, if complete, are encyclopedic; and the student is apt to lose sight of the philosophy in the mass of the facts. This book is intended to supplement the ordinary manuals. In its first part the composition of organic compounds is considered. In the second, their physical properties. And in the third, their general behavior. The statements made are clear, concise and accurate, and the principles laid down are illustrated by numerous examples. The book is well translated, and its mechanical execution is neat and substantial.

7. *Photographic action of Electromagnetic Waves.*—FRANZ VON DOBRZYNSKI claims to have obtained photographic indications of electromagnetic waves in air, employing the method of producing these waves which has been described by Hertz. The plane of the negatives either included the axis of the vibrator or was at right angles to it, and the time of exposure was three hours. The action was visible after development by the appearance of alternating bright and dark bands across the direction of vibration of the waves, or by the appearance of dark bands in the direction of the vibration. The author concludes that waves of from 0·6 to 20 cm. are effective, and promises a further account of his experiments.—*Wiener Berichte*, Oct. 9, 1890. J. T.

8. *Measurement of Dielectric Constants by means of Hertz's Phenomenon.*—E. LECHER has continued the work of J. J. Thomson on this subject, and has compared the results obtained by the method of electrical oscillations with those obtained by his other

methods, which are fully described in Lecher's paper. The following table gives the results :

Time of charging in seconds.	Dielectric constants. Mirror glass.	Solin glass.	Rubber.	Petroleum.	Water.
	0·8797 cm.	0·4338 cm.	0·7164 cm.	1·9272 cm.	1·9342 cm.
0·5	4·67	4·64	2·64	Not measured.	
0·0005	5·34	5·09	2·81	235	∞
0·00000003	7·31	6·50	3·01	242	∞

These results show a marked increase in the constant when it is measured by the quick method of oscillation. The author discusses the cause of this variation and points out that Hertz's phenomenon is so complicated that slower methods of charging are likely to give better results in determinations of the dielectric constants.—*Ann. der Physik*, No. 1, 1891, pp. 142–153. J. T.

9. *Limit of Solar Spectrum in the Ultra Violet.*—Dr. O. SIMONY has obtained photographs of the solar spectrum on the top of the Peak of Teneriffe and also at Courtenay. The following results were obtained :

Photographs obtained at	Altitude in meters.	Wave length. Last trace.	Beginning of end.
Teneriffe	3700	292·2	293·7
Courtenay	170	284·8	298·0

—*Comptes Rendus*, Dec. 22, 1890. J. T.

10. *Recent progress in Spectrum Analysis.* In the Johns Hopkins University Circular for Feb., 1891, Prof. H. A. ROWLAND gives an account of recent work done at Baltimore in the study of the spectra of the various elements and the identification of the lines in the solar spectrum. The spectra of all the known elements, with the exception of a few gaseous ones or those too rare to be obtained (see list below), have been photographed in connection with the solar spectrum, from the extreme ultra violet to the D line, and eye observations have been made to the limit of the solar spectrum. In connection with this work, the spectra of some of the elements have been drawn on a large scale for publication, and the greater part of the lines in the map of the solar spectrum have been identified. The following table, from the author's observations, gives the elements in the sun, arranged first according to intensity and second according to number of lines in the solar spectrum. Lists of doubtful elements, those not identified and finally those which have not yet been tried are given also.

Of the solar elements, attention is called to silicon, vanadium, scandium, yttrium, zirconium, glucinum, germanium, erbium as possibly new. Silicon has lines at wave lengths 3905·7, 4103·1, 5708·7, 5772·3 and 5948·7. That at 3905·7 is the largest and most certain; that at 4103·1 is claimed also by manganese.

These tables are regarded as preliminary only, especially the order in the first portion. However, being made with such a powerful instrument and with such care in the determination of impurities, they must still have a weight superior to most others

published. The substances under the head of "Not in the Solar Spectrum" are often placed there because the elements have few strong lines or none at all in the limit of the solar spectrum, when the arc spectrum, which was used, is employed. Thus boron has only two strong lines at 2497. Again, the lines of bismuth are all compound and so too diffuse to appear in the solar spectrum. Indeed, some good reason generally appears for their absence from the solar spectrum. Of course, this is little evidence of their absence from the sun itself; were the whole earth heated to the temperature of the sun, its spectrum would probably resemble that of the sun very closely.

Elements in the Solar Spectrum.

According to Intensity.		According to Number.	
Calcium.	Zirconium.	Iron (2000 +)	Magnesium (20 +)
Iron.	Molybdenum.	Nickel.	Sodium (11).
Hydrogen.	Lanthanum.	Titanium.	Silicon.
Sodium.	Niobium.	Manganese.	Strontium.
Nickel.	Palladium.	Chromium.	Barium.
Mangnesium.	Neodymium.	Cobalt.	Aluminium (4).
Cobalt.	Copper.	Carbon (200 +)	Cadmium.
Silicon.	Zinc.	Vanadium.	Rhodium.
Aluminium.	Cadmium.	Zirconium.	Erbium.
Titanium.	Cerium.	Cerium.	Zinc.
Chromium.	Glucinum.	Calcium (75 +)	Copper (2).
Manganese.	Germanium.	Scandium.	Silver (2).
Strontium.	Rhodium.	Neodymium.	Glucinum (2).
Vanadium.	Silver.	Lanthanum.	Germanium.
Barium.	Tin.	Yttrium.	Tin.
Carbon.	Lead.	Niobium.	Lead (1).
Scandium.	Erbium.	Molybdenum.	Potassium (1).
Yttrium.	Potassium.	Palladium.	

Doubtful Elements.—Iridium, osmium, platinum, ruthenium, tantalum, thorium, tungsten, uranium.

Not in Solar Spectrum.—Antimony, arsenic, bismuth, boron, nitrogen (vacuum tube), caesium, gold, indium, mercury, phosphorus, rubidium, selenium, sulphur, thallium, praeseodymium.

Substances not yet tried.—Bromine, chlorine, iodine, fluorine, oxygen, tellurium, gallium, holmium, thulium, terbium, etc.

In conclusion, Prof. Rowland adds, "Even after comparing the solar spectrum with all known elements, there are still many important lines not accounted for. Some of these I have accounted for by silicon and there are probably many more. Of all known substances this is the most difficult to bring out the lines in the visible spectrum although it has a fine ultra-violet one. Possibly iron may account for many more, and all the elements at a higher temperature might develop more. Then, again, very rare elements like scandium, vanadium, etc., when they have a strong spectrum, may cause strong solar lines and thus we may look for new and even rare elements to account for very many more. Indeed, I find many lines accounted for by the rare elements in gadolinite, samarskite and fergusonite other than yttrium, erbium, scandium, praeseodymium, neodymium, lanthanum and cerium, which I cannot identify yet and which may be without a name. For this reason, and to discover rare elements, I intend finally to

try unknown minerals, as my process gives me an easy method of detecting any new substance or analyzing minerals however many elements they may contain."

II. Geology and Mineralogy.

1. *Discovery of fish remains in Lower Silurian Rocks.*—At a meeting of the Biological Society of Washington, on February 7th, 1891, Mr. Charles D. Walcott, of the U. S. Geological Survey, announced the discovery of vertebrate life in the Lower Silurian (Ordovician) strata. He stated that "The remains were found in a sandstone resting on the pre-Paleozoic rocks of the eastern front of the Rocky Mountains, near Cañon City, Colorado. They consist of an immense number of separate plates of placoganoid fishes and many fragments of the calcified covering of the notochord, of a form provisionally referred to the Elasmobranchii. The accompanying invertebrate fauna has the facies of the Trenton fauna of New York and the Mississippi valley. It extends upward into the superjacent limestone and, at an horizon 180 feet above the fish beds, seventeen out of the thirty-three species that have been distinguished are identical with species occurring in the Trenton limestone of Wisconsin and New York.

"Great interest centers about this discovery from the fact that we now have some of the ancestors of the great group of placoderm fishes which appear so suddenly at the close of the Upper Silurian and in the lower portion of the Devonian groups. It also carries the vertebrate fauna far back into the Silurian and indicates that the differentiation between the invertebrate and vertebrate types probably occurred in Cambrian time."

Mr. Walcott is preparing a full description of the stratigraphic section, mode of occurrence and character of the invertebrate and vertebrate faunas for presentation at the meeting of the Geological Society of America, in August, 1891.

2. *On Burrows and Tracks of Invertebrate Animals in Palæozoic Rocks, and other Markings;* by Sir J. William Dawson. (Quart. Jour. Geol. Soc., November, 1890, vol. xlvi. (London) pp. 595–618).—The author states that in this paper it is intended to contribute "Some recently acquired facts to the solution of questions connected with these often problematical markings." It is a well-known fact that the distinguished author, who has contributed far more to the elucidation of the American pre-Carboniferous flora than any other paleo-botanist, has not claimed botanical affinities for many of the so-called fossil plants; but, on the contrary, has adduced proof of their invertebrate or inorganic relationship. Dr. Dawson's investigations as a geologist and paleontologist, who has carefully studied both invertebrate and plant remains of the Paleozoic rocks, gives him a richer store of facts in reference to these organisms than it had been the fortune of many other paleontologists to possess who described and named many of the fossils under consideration.

The *Bilobites* are considered in the second section of the article and it is concluded that "so far as American examples are concerned" the forms referred to the following genera, viz: *Rusichnites* Dn. = *Rusophycus* Hall, *Arthrichnites* Dn. = *Arthrophycus* Harlan, *Cruziana* D'Orb., *Climactichnites* Logan. *Fræna* Rouault and *Crossochorda* Schimper (in part), were the burrows and tracks of marine animals, generally Crustaceans, although some may have been produced by Chætopod worms.

Scolithus linearis Hall and *S. Canadensis* Billings, from the Potsdam sandstone, are worm-burrows, as is clearly shown by the photograph of a slab with characteristic *Scolithus* markings from Perth, Ontario. A similar origin was assigned to the *Fucoides graphicus* Van. and *F. verticalis* Hall, from the Portage sandstones of New York, by Dr. H. S. Williams in Bulletin No. 41 of the U. S. Geological Survey. The genus *Sabellarites* is proposed for certain forms, regarded as worm tubes, from the Black River limestone and the Quebec group.

It must not be inferred that Sir William has rejected all of the Silurian and Devonian fossil algæ; because, there are certain types which he as emphatically affirms are true Fucoids. As examples may be cited *Buthotrephis gracilis* Hall of the Cambro-Silurian and *B. Grantii* Dn., from the Niagara group of Canada. Although the distinction between branching plants and branching tracks seems very difficult to the superficial observer, it is stated as a general rule by the author, that "The latter are generally of the nature of more or less cylindrical bodies, diverging or radiating from a common center; while the former display either alternate ramification or bifurcation."

Perhaps section VIII, which closes the paper, is the one of most general interest and about which there is the greatest diversity of opinion. The author briefly describes "Rill-marks, as distinguished from animal- or plant-impressions," and mentions "the genera *Dendrophycus*, *Delesserites*, *Vexillum*, *Aristophycus*, *Chloëphycus*, *Tricophycus* of authors as examples of genera which contain, or consist of, examples of Rill-marks." Two figures are given of these rill-markings from the Carboniferous of Nova Scotia, which are stated to be "taken from surfaces unquestionably sculptured by water," and it appears that one of these, fig. 18, is very similar to forms that have been described by Lesquereux and Newberry as *Dendrophycus*. Recently Professor Joseph F. James has called the *Dendrophycus triassicus* of Newberry a rill-mark (Am. Naturalist, vol. xxiii, p. 1080), which has called forth a rejoinder from its describer, re-affirming his original opinion (*Idem.*, vol. xxiv, pp. 1068, 1069). C. S. P.

3. *Annual Report for* 1889 *of the Geological and Natural History Survey of Minnesota*, N. H. WINCHELL, *State Geologist.*—This eighteenth annual report of the Minnesota Survey contains a report of field observations by N. H. Winchell, made by him and Mr. H. V. Winchell. These include an account of the Mesabi iron range of the crystalline rocks of the Minnesota Valley, the discovery of gold in the Keewatin in northern Minne-

sota, and other notes on the Archæan rocks, and iron ores of other localities. A dozen pages are devoted to further observations on the typical Huronian and on the rocks about Sudbury, Ontario. 150 pages are occupied with a review by Prof. Alexander Winchell, of the opinions of various American authors "on the older rocks," with the purpose of preparing the way for the settlement of the many mooted questions on the Archæan. The status of of the Huronian is one of them—a topic discussed by the author at length, also in a paper just published by the Geological Society of America.

4. *Remarks on the Perisomic Plates of the Crinoids;* by CHARLES R. KEYES. (Communicated.)—In an important contribution recently made to crinoid morphology* the data have been derived largely from fossil material. This memoir deals chiefly with the structural elements of the ventral covering in several groups of stalked echinoderms; the "interradial" plates; and the relations these hold to one another and to those of the tegmen. Heretofore some authors have imagined that the disk of paleozoic crinoids was overlaid by a second covering which was not present in the recent forms, but this view is manifestly erroneous. As to the plates between the rays, all writers have discriminated between "calyx" and "disk" interradials, the former term being applied to the massive well-formed plates of the earlier crinoids; the latter to the small irregular perisomic pieces of the later forms. Contrary to the generally held opinion the investigations of Messrs. Wachsmuth and Springer indicate that all plates between the rays and their subdivisions are parts of the same element and that in geologic times the rigid integument, such as is found in the later Camarata, gradually became evolved from the thinly plated disk of early species. The heavy "interradials" are therefore to be regarded as modified perisomic pieces.

In regard to the ambulacra observations show that these features may be tegminal or subtegminal even among species of the same genus; and that they are more frequently exposed in the earlier crinoids. From a comparison of young and adult individuals it is further assumed that in the latter forms the ambulacra are often exposed near the margin of the tegument while in other species they are altogether hidden from view. Thus the tegminal ossicles encroach from each side of the ambulacra and finally close above them, crowding the ambulacral skeleton inward.

In the Fistulata all plates between the ambulacra, and between radials and orals are perisomic. In most of the species the ventral sac is porous, while in others there is anterior to the inflation a perforated plate like the madreporite of the urchins. The Larviformia are now restricted to forms having the ventral surface composed of orals only, with no perisomic plates.

* Perisomic Plates of the Crinoids. By Charles Wachsmuth and Frank Springer. Proc. Acad. Nat. Sci. Phila., 1890, pp. 345–392, with two plates.

The origin and development of the anal plates in the Fistulata is of peculiar interest. Some time ago Mr. F. A. Bather in discussing the subject distinguished two separate pieces; the "radianal" or azygous ossicle and the "brachianal" or special anal plate. As to the first there now seems to be but little doubt that it is actually the lower section of the compound right-posterior radial which in some groups served as an anal. Regarding the second plate Messrs. Wachsmuth and Springer differ very materially from Mr. Bather, in considering that there is no sinking of the anal tube, nor a shifting of the radianal; and that with the widening of the anal area, a new plate was introduced between the radials. The radianal does not appear to change its position, but rests within the angle of two basals. The plate, which in *Iocrinus* rests upon the radials, and which, in *Poteriocrinus* is said to have passed down to the basals, is a plate of the tube.

5. *Bulletins* 2 *and* 3 *of the Geological Survey of Missouri;* ARTHUR WINSLOW, *State Geologist*, December, 1890.—Bulletin No. 2, covering 158 pages, is occupied with a bibliography of the geology of Missouri, by F. A. SAMSON. It derives special value from its giving full lists of the fossils described in the various publications referred to, and notes on other topics. Bulletin No. 3 contains a paper by G. A. E. LADD on Clay, Stone, Lime and Sand industries of St. Louis city and county; and another by A. E. WOOWARD on the mineral waters of Henry, St. Clair, Johnson Benton counties. The first of these valuable papers is illustrated by several photo-engravings.

6. *Second Geological Survey of Pennsylvania: Oil and Gas Region, I* 5. pp. i–viii, 1–356, maps, 1890; *Atlas Southern Anthracite Field, Part III., AA.* 1889; *Dictionary of Fossils,* volumes II and III, P4, pp. 439–914, 915–1283, 1889.—Report I 5 discusses the progress and condition of the oil and gas regions during 1887 and 1888, and presents statistical tables showing the steady decline in the yield of both these products. The theory of hydrostatic pressure, as applied to gas pressure in wells, is opposed by Mr. Carll, the author of this report. The Dictionary of Fossils is brought to a completion. While of considerable value as a compilation, it lacks the elements of a critical scientific work.

7. *Geological Survey of New Jersey.*—Final Report of the State Geologist, vol. ii, Trenton, 1889. The first volume of the final report was noticed in vol. xxxvii, 1889 (p. 232). This second volume is devoted to the Natural History of the State and contains a catalogue of minerals found in New Jersey by F. A. Canfield (pp. 1–24) and a catalogue of plants by N. L. Britton (pp. 25–619). Tables giving the distribution of the plants close the volume.

8. *On a group of volcanic rocks from the Tewan Mountains, New Mexico, and on the occurrence of primary quartz in certain basalts;* by J. P. IDDINGS. 32 pp., 8vo. Bulletin 66, of the U. S.

Geol. Survey, 1890.—The following important conclusions are deduced by Mr. Iddings from his study of the Tewan volcanic rocks.

(1) The collection of rocks from the Tewan mountains, New Mexico, though small, shows a gradual transition in mineral composition from rhyolites through andesitic rocks to basalts. (2) The whole series is characterized by a variable amount of porphyritical quartz in rounded grains, which is very noticeable in some of the basalts. (3) These quartzes are primary secretions or crystallizations from the molten magma and exhibit no definite relation to its chemical composition, being present, in or absent from, rocks of similar chemical composition. (4) Their production is to be referred to certain physical conditions attending some earlier period of the magma's existence. Mr. Iddings also infers (5) from analogy with the occurrence of iron-olivine in rhyolitic obsidian, that the formation of the quartz in the basalt took place through the influence of water-vapor while the magma was under considerable pressure.

9. *Elementary Geology ;* by CHARLES BIRD. pp. i–vi, 1–248, 247 illustrations and map. Longman's Elementary Science Manuals, 1890.—A convenient compilation of the general facts of Geology in attractive form and especially adapted to the British student. It is designed primarily to arouse an interest in natural phenomena and outdoor objects, and also to enable the student to gain, through examination, a South Kensington certificate. In subsequent editions, it would be well to orient a number of the illustrations which now are placed in various unnatural positions.

10. *Allgemeine und Chemische Geologie.*—Dritter band. Erste Abtheilung. Allgemeine Geologie von JUSTUS ROTH, 210 pp. Berlin, 1890, (Wilhelm Hertz). The third volume is now begun of this well known and highly valued work. The greater part of the number is given to the discussion of the subject of metamorphism, more especially that of local or contact nature. So many important facts and observations have been gradually collected on this last subject, that their collection together and orderly arrangement are a great advantage to all interested in this department of geology.

11. *On Black Rutile from the Black Hills ;* by W. P. HEADDEN, with a note on the crystals by L. V. PIRSSON (communicated).—The material which forms the subject of this note was found among some specimens of tin ore in the cabinet of the School of Mines of South Dakota. The specimen was without label and no locality was attached to it; it is, however, quite certain that it is from the Harney Peak district of the Black Hills, probably from the immediate neighborhood of the Etta mine, Pennington Co. The crystals formed aggregates usually surrounded by and always associated with muscovite in a mass of feldspar. The crystals are small, deep black and have a brilliant metallic luster; in form they have the aspect of orthorhombic prisms terminated by a macrodome. Hardness, 6; Sp. gravity, 5·294. Streak and powder, grayish-black. BB. unchanged and

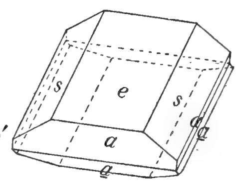
infusible with phosphorus salt, reacts for titanic acid and iron. Two analyses of carefully selected material gave the following results:

TiO_2	90·78	90·80
FeO	8·10	7·92
SnO_2	1·32	1·38
MnO	trace	trace
	100·20	100·10

The iron is assumed to be present as FeO, but the state of oxidation was not determined. The presence of SnO_2 in the mineral was known before the material for these analyses was selected and with the greatest care no cassiterite could be recognized in the mass; as the larger number of the fragments showed portions of crystal surfaces, and as the material is easily and completely decomposed by potassic hydric sulphate it is very improbable that the stannic oxide in the analysis is due to the presence of admixed cassiterite. Since the crystals did not bear any obvious resemblance to the known forms of titanic oxide, they were sent to E. S. Dana and were identified by him as twins of rutile, unusual in form as they are remarkable for their high specific gravity. Since then they have been more minutely studied by Mr. Pirsson, who gives the following account of them.

Note by L. V. Pirsson.—The crystals, of which a series of seven was examined, are not suited for accurate measurement, the faces giving faint and diffused reflections of the signal of the goniometer and sometimes no reflection at all; this is due to the fact that the surfaces are all more or less etched and pitted, while the polished points between are curved or broken. By using a condenser and the δ ocular of Websky enough light was collected in several cases to give signals which afforded fairly accurate measurements. These showed the following forms to be present: *a*, *i-i*, (100); *e*, 1-*i*, (101); *s*, 1, (111). These were identified by the following calculated and measured angles:

	Calc.	Meas.
$e \wedge a$ $(101 \wedge 100)$	57° $12\frac{3}{4}$′	57° 10′, 57° 20′
$a \wedge a$ $(100 \wedge 1\bar{0}0)$	65° $34\frac{1}{2}$′	65° 50′, 66° 08′
$s \wedge \bar{s}$ $(111 \wedge 1\bar{1}\bar{1})$	56° $52\frac{1}{2}$′	56° 50′, 56° 45′, 56° 38′



There were also a few other forms present on some of the crystals, but these could not be identified with any certainty for the reasons mentioned. The apparent orthorhombic symmetry of these crystals, due to the extension of one pair of unit pyramids and the absence of the other two is shown in the accompanying figure. It illustrates the largest crystal examined, which is about 3mm broad and wide by nearly 2mm thick. That end of the crystals where the re-entrant angle due to twinning should appear is always broken and imperfect as if they had been attached at that point. Somewhat similar forms of rutile have been described by Miklucho-Maclay, Jahrb. Min., ii, 88, 1885.

12. *Occurrence of Tin in Central Texas*; by THEODORE B. COMSTOCK. (Communicated.)—The recent newspaper reports of the existence of tin ores in Central Texas have had origin in the official announcement in November by the State Geologist of the discovery by the writer of good specimens of *cassiterite* in several localities in Llano and Mason Counties. As yet no workable deposits have been found, but the indications are such as to encourage prospecting, if conducted in accordance with the knowledge of the structure acquired by the Geological Survey.

The *cassiterite* has all been found in a belt of the lowest Archean (Burnetan) rocks, trending N. 75° W. through Llano and Mason Counties, with a short extension eastward across the Colorado River into Burnet County. In many places this field is complicated by the effects of later upheavals, the structure in detail having been described in the First Annual Report of the Texas Geological Survey.* Some very interesting observations concerning the associations of the tin ore, its special area of distribution along a single axis of the Burnetan system, and its relations to an interesting series of rare minerals can only be hinted at here, but they will be shortly announced in the 2d Annual Report now in the printer's hands. The writer has made a thorough examination of the district and has prepared accurate maps and sections to illustrate the stratigraphy. Very much of the material which has been reported as tin ore from this district is keilhauite, tourmaline or black garnet, but the cassiterite has been collected by members of the writer's Division of the Survey from four localities besides the one in which an old furnace was discovered with tin globules in the slag dump.

Austin, Texas, Jan. 24, 1891.

13. *Brief notices of some recently described Minerals.*—PINAKIOLITE is a new borate of manganese and magnesium described by Flink from Långban, Wermland, Sweden. It occurs in small orthorhombic crystals imbedded in limestone. Cleavage brachypinacoidal; hardness = 6; sp. gravity = 3·881; color black. An analysis, after deducting impurities, gave:

B_2O_3	Mn_3O_4	Fe_3O_4	MgO	CaO	PbO
16·05	50·63	2·12	29·30	1·12	0·78 = 100.

For this the formula $3MgO.B_2O_3+MnO.M_2O_3$ is calculated which brings it into relation with ludwigite and sussexite.—*Zs. Kryst.*, xviii, 361, 1890.

TRIMERITE is a silicate of beryllium, manganese and calcium; also described by Flink (l. c.) from the Harstig mine, Wermland. The crystals have a hexagonal form, but are shown optically to be pseudo-hexagonal and twins of triclinic individuals. Cleavage basal; hardness 6–7; sp. gravity = 3·474; color pink. An analysis gave:

SiO_2	BeO	MnO	FeO	CaO	MgO
39·77	17·08	26·86	3·87	12·44	0·61 = 100·63.

* Preliminary Report on the Geology of the Central Mineral Region of Texas. By Theo. B. Comstock, F.G.S.A. In 1st Ann. Rep't of State Geologist, 1889, pp. 255–267, etc.

This gives the formula $Be_2SiO_4 . Mn_2SiO_4$, or equivalent to phenacite+tephroite, and Brögger (ib., p. 377) shows that in form also it forms a transition from the rhombohedral phenacite to the orthorhombic tephroite.

HINTZEITE is a new borate from Stassfurt, described by Milch from Stassfurt. It occurs in small monoclinic crystals, colorless or white, imbedded in pinnoite. Hardness=4·5–5; sp. gravity 2·127. Analysis by Baurath gave:

B_2O_3	MgO	K_2O	Na_2O	Cl	H_2O
52·39	13·80	8·14	0·39	0·35	23·83 = 98·90.

For this the formula $KMg_2B_9O_{16} . 8H_2O$ is calculated.—*Zs. Kryst.*, xviii, 478.

HEINTZITE is described as a new borate by Luedecke. It occurs in monoclinic crystals associated, like the above Hintzeite, with pinnoite, and although the descriptions do not entirely agree it can hardly be doubted that they are the same mineral. There is a striking similarity in the angles given. Analysis gave:

B_2O_3 60·53 MgO 12·23 K_2O 7·39 H_2O 19·85 = 100.

For this the formula is calculated $H_2KMgB_{11}O_{20} . 6H_2O$.—*Ibid.*, p. 481.

CASTANITE is a hydrous ferric sulphate described by Darapsky from the Sierra Gorda, S. America. It is found in prismatic crystals of a chestnut-brown color. Hardness=3; sp. gravity=2·18. Analysis gave:

SO_3 33·80 Fe_2O_3 33 92 H_2O 30·76 barite 1·15 = 99·63.

The formula is $Fe_2O_3 . 2SO_3 . 8H_2O$, or like that of amarantite except that it contains one more molecule of water.—*Jahrb. Min.*, ii, 267, 1890.

FALKENHAYNITE is a sulphantimonite of copper, from Joachimsthal, allied to wittichenite. It is only known in a single specimen in which it is associated with chalcopyrite and siderite. An analysis after deducting a large amount of a carbonate of iron and magnesium, also quartz, gave:

S	Sb	As	Bi	Cu	Fe	Zn
26·21	23 10	4·77	0·32	39·51	4·20	1·89 = 100.

Assuming further the existence of chalcopyrite and deducting this, the formula $Cu_6Sb_2S_6=3Cu_2S . Sb_2S_3$ is obtained.—*Jahrb. Geol. Reichs.*, xl, 433, 1890.

14. *Diamonds in Wisconsin.*—The finding of a few diamonds in the gold gravels of Plum creek in Rock Elm township, Pearce county, Wisconsin, is noted by G. F. KUNZ. The stones weighing $\frac{25}{32}$, $\frac{7}{16}$ and $\frac{3}{32}$ carat were specially examined. The sand contains, besides quartz grains, magnetic and titanic iron, garnets, monazite, etc. The diamonds are stated to have been found in 1887 by G. H. Nichols of Minneapolis.

15. *Native Nickel of terrestrial origin.*—A. SELLA notes the existence, in the auriferous sands of the stream Elvo near Biella,

Piedmont, of metallic grains, of an iron-nickel. They are malleable, strongly magnetic, and in appearance resemble native platinum; the specific gravity is 7·8. An analysis by Mr. Mattirola showed that they consisted of nickel (and cobalt) 75·2, iron 26·6 = 101·8, or conforming nearly to Ni_3Fe. It will be remembered that grains of a nickel-iron have been recently found in New Zealand, and grains of nickel (oxide?) were some years since reported from the Fraser river sands.—*C. R.* cxii, 171, 1891.

16. *Index der Krystallformen von* Dr. V. Goldschmidt. Band III, Heft 4, 5, pp. 183–320.—This important work, commenced nearly five years ago, is nearly completed with the parts now issued. It has been a laborious undertaking, patiently and faithfully carried through. The species here included range from Tantalite to Wurtzite.

III. Botany and Zoology.

1. *Recherches sur la croissance terminale de la tige des phanerogames*, by H. Douliot (Ann. des sci. nat. (bot.) ser. vii, tome xi, pp. 283–350, pls. 13–19).—The existing disagreement in regard to the apical growth of the higher plants is of too long standing to be finally settled by the unconfirmed results of any single investigation. Each new work lends plausibility to one view or another; but only in the agreement of a number of observers can ultimate certainty be attained. It is accordingly worthy of note that in the work bearing the above title the author, to a great extent, confirms and extends the interesting observations which Dingler published some time ago. In the case of the gymnosperms, it will be remembered, Dingler has, in recent years, stood alone in affirming that terminal growth takes place by the activity of a single apical cell. Hofmeister held this view, but from the time of his investigations in 1851 until the appearance of Dingler's work in 1882, no one was able to show the presence of single apical cells among plants of this group, except in the embryonic stages. As examples of the gymnosperms Dr. Douliot has studied a considerable number of species from the different tribes and genera of the *Coniferæ*, and also *Ephedra distachya* among *Gnetaceæ*. The *Cycadaceæ* do not appear to have been examined, probably owing to the great difficulty of obtaining material of them. In all the plants studied single apical cells have been more or less clearly made out. The results were especially satisfactory in plants examined during the period of rapid growth, while in material collected during the resting stages the apical cells were much more difficult to discover, if distinguishable at all. The figures in the plates which accompany the paper are, in some cases, clear; in others not very convincing. The segments supposed to have resulted from the successive divisions of the apical cell are often so irregular in outline that one must trust entirely to the represented thickness of the cell-walls to determine their limits. Among the angiosperms a large number

of plants were investigated with the result that the tissues are differentiated either from two or from three initial layers which arise independently, each by the repeated divisions of one of its cells. Among the monocotyledons there are usually two such initial layers, while in dicotyledons the occurrence of three is more common. B. L. R.

2. *Typical Elms and other trees of Massachusetts. Introduction by* OLIVER WENDELL HOLMES, *descriptive text by* LORIN L. DAME, *and illustrations by* HENRY BROOKS; folio of 90 pp. with 58 plates; Boston, 1890.—While not in the narrower sense a scientific work this book is eminently deserving of mention here as containing much that is of interest to the botanist. With great care Messrs. Dame and Brooks have searched out, described, and illustrated examples of many different types of elms, maples, oaks, and other trees; and their work shows, in a striking way, what remarkable diversity of form is manifested by individuals of the same species. The plates, which have been excellently prepared by the photogelatine process, represent, in most instances, the entire tree, showing very clearly its characteristic habit, while a rod of given length placed near its base gives an easy means of judging its size. As the title would indicate, preeminence is given to the American elm, and over twenty more or less clearly marked types of this magnificent tree are represented. The introductory chapter by Dr. Holmes is a graceful contribution to a work, which was long ago suggested by him, and which has been carried out thoroughly in his spirit. B. L. R.

3. *Ueber die Balken in den Holzelementen der Coniferen;* by CARL MÜLLER (Berichte der deutsch. bot. Gesellsch., viii, pp. 17–46.)—The occasional presence of slender cross-bars or "beams" of cellulose in the tracheids of the *Coniferæ* was first mentioned by Sanio, and has since been noted by a number of observers, none of whom, however, have, until now, made any extended study of this curious phenomenon. In the present paper Müller summarizes the results of a series of observations to be described in detail at some future time. It appears from these studies that such beams are of much more common occurrence than heretofore supposed. While considerably more frequent in some species (e. g. *Araucaria Brasiliensis* and *Ginko biloba*) than in others, in none of the twenty-eight *Coniferæ* examined were they entirely wanting. Occurring alike in stem, root, and branches they are to be found not only in the wood, but in the cambium and bast as well; and, although generally seen in the tracheids and sieve-tubes, they have occasionally been observed in the parenchyma of the xylem and cambiform elements of the bast.

These peculiar structures among the *Coniferæ* recall, of course, the similar cellulose bars occurring elsewhere (e. g. in *Caulerpa*) as well as the crystal-bearing beams described by Rosanoff. On grounds of their peculiar origin and development, however, Müller is inclined to regard them as distinct from other similar structures, and suggests that they be called the beams of Sanio

(Sanio'sche Balken). The structures in question, which are, of course, not to be confused with the trabeculæ or wall-thickenings in scalariform ducts, extend radially through the elements in which they occur, and, although occasionally single, often recur in a great number of successive elements in the same radial row. Wherever such a series of beams occurs in the xylem, a corresponding one is to be found in the phloem, the two being either continuous through the cambial layer or separate, both ceasing at equal distances from the cambium. After describing the occurrence and character of these beams Müller proceeds to consider several of the possible ways in which they may arise. While other theories prove unsatisfactory, he shows by very clear figures that the beams are probably due to an infolding of the radial walls of the cambial cells. Such a fold having been formed, its connection with the radial wall is resorbed and the greater part of the fold remains as a cross-bar, or plate extending from one tangential wall to the other. As the cambial cell divides, the beam-like structure extends through both daughter-cells, and so arise the radial rows of beams. By further resorption the beam in the cambial cell gradually diminishes in size and finally disappears, which accounts for the fact that the rows are not always continuous from wood to bast. In regard to the mechanical relations of the beams, Müller finds that, during their development, they are stretched, but often at later stages compressed as in the crushing of the bast by the tension of the bark. They then become variously curved. Unfortunately no data for determining the physiological significance of these interesting structures have as yet been found. B. L. R.

4. *Cultures experimentales dans les Alpes et les Pyrénées.* (Revue générale de botanique, II, pp. 513–546, pls. 20–22).—In this paper Professor Gaston Bonnier describes an extensive series of alpine cultures, which he has been carrying on for some years. His purpose has been to determine more accurately the influence of altitude upon the characters of different phanerogams, and to observe the limits to which variation due to this cause may extend. In the present communication he describes merely the modifications of the external characters attending growth at high altitudes, and reserves the discussion of the anatomical changes for some future occasion. While his observations concerning the external traits contain little that will be new to anyone familiar with the nature of alpine vegetation, the methods employed in the cultures are very interesting, and might well be applied by American botanists so situated that they can study mountain vegetation. To estimate the modification which is due solely to altitude, it is necessary to remove so far as possible all other differences in the conditions under which cultures of the same species are made. This is not an easy task, but is of course essential to accurate results. No satisfactory conclusions, for instance, could be reached by comparing specimens transplanted to higher or lower altitudes with those growing undisturbed at

their natural level; for the changes in the former would be due not only to altitude but in great part to the transplanting and acclimatization in new situations. Differences of soil, exposure, encroachment of neighboring plants and other such factors would of course introduce like inaccuracy into the results. Professor Bonnier's ingenious methods of avoiding these difficulties have been in brief as follows:

The root or base of a plant has been taken from a medium altitude and divided into two equal parts, one of which was transplanted to a higher altitude, the other to an equal distance below its original position under similar conditions of exposure. In this way the disturbing influence of acclimatization is lessened by half; while as both plants are removed from their original situation the effect of transplanting may be presumed to be equal in both cases. The plants have in all instances been placed in soil brought from the spot from which they were taken. The species selected for experimentation have been mostly such as were spontaneous in the regions where they were cultivated; and lastly no comparisons have been made until the plants have become so far acclimatized in their new situations as to bloom and bear fruit. Professor Bonnier has made over two hundred such cultures, choosing his plants from widely different orders. Some of the cultures were begun as early as 1884, and more than half were still alive at the time of writing. The observed effects of high altitude upon the growth of phaenogams have been a smaller form, shorter internodes, a comparatively large development of subterranean parts, leaves smaller, thicker, and brighter green, and flowers more highly colored. Some of these traits vary directly with the altitude, while others, as the greenness of the leaves, have been observed to reach an optimum at a certain height, beyond which the plants in these regards come more or less to resemble specimens growing at lower levels. Certain plants, as *Chenopodium Bonus-Henricus*, appear to undergo little or no modification for differences of altitude. B. L. R.

5. *Insecta;* by ALPHEUS HYATT and J. M. ARMS.—Guides for Science Teaching, No. viii. Boston Society of Natural History, pp. i–xxxiii, 1–300, 223 illustrations, 1890.—The methods upon which this work is based will recommend themselves to students and teachers, as they furnish a philosophical account of the various members of the class and of the formation and interdependence of the various organs and functions of the organism. The characters of *Thysanura* represent the key to the system of modern classification, and the Thysanuran stock is taken as the primitive type from which have been derived the present sixteen orders of insects. A phylogenetic arrangement, illustrated graphically by diverging and parallel bars, expresses in a satisfactory way the relations of the orders, while a plane at right angles to the axial stock represents the surface of the earth. The authors conclude that the thorax is primarily a three segmented region, and has become modified into greater complexity by

secondary sutures. The concentration of the thoracic region is referred to the reactions from the wings and legs. In a form such as *Pulex*, in which the wings are reduced to mere scales and the legs developed for leaping, the thorax loses its complex modifications, and the rings become distinct and closely resemble the abdominal segments. C. E. B.

IV. Miscellaneous Scientific Intelligence.

1. *Fifth International Congress of Geologists.*—The committee of organization, of which J. S. Newberry is chairman, and H. S. Williams and S. F. Emmons, secretaries, have recently issued a circular which makes the following announcements:

The Bureau of the International Congress of Geologists has decided that its Fifth Session shall be held at Washington, and the date of the session has been fixed for the last Wednesday (26th) of August, 1891.

The annual meeting of the American Association for the Advancement of Science and the summer meeting of the Geological Society of America will be held in the same city during the preceding week.

Requests for inscription as members of the Congress should be addressed to the secretary's office, 1330 F street, Washington, D. C. The fee for membership has been fixed at two and a half dollars ($2.50). The receipt of the treasurer entitles the subscriber to a member's card, as well as to the Compte Rendu and other ordinary publications of the Congress.

2. *Alabama Industrial and Scientific Society.*—This Society was recently organized at the University of Alabama with 70 members. Its objects are the promotion of the industries of the State, and the furtherance of the scientific investigation of the problems arising in civil and mining engineering, geology, smelting, and the manufacture of coke. The president for 1891 is C. C. Cadle. The society will meet three or four times a year at different places in the State, for the reading and discussion of papers, which will afterwards be published. A meeting was held in Birmingham, January 28th, 1891.

3. *Transactions of the Meriden Scientific Association*, vol. iv, 1889–1890, 89 pp.—This volume contains a sketch by Rev. J. I. Pettee, of the life and work of the Connecticut geologist, J. G. Percival, with a portrait; also articles on sewage by G. L. Cooper; on the topographical survey of Connecticut, on geological features of Meriden, on *Cycadinocarpus Chapinii*, a fossil plant from the Durham shales, by Rev. J. H. Chapin; on the pre-Columbian discovery of America by the Northmen, by C. H. S. Davis.

4. *A Move for Better Roads.* Essays on road-making and maintenance and road laws, for which prizes or honorable mention were awarded through the University of Pennsylvania, by a committee of citizens of Philadelphia, with a synopsis of other contributions and a review by the secretary, Lewis M. Haupt; also

an introduction by WILLIAM H. RHAWN, Chairman, 319 pp. Philadelphia, 1891.—The subject treated of in this volume, as is shown in the above title given in full, is eminently practical and one demanding more attention than it has yet received in this country.

5. *Die Cordillere von Mérida nebst Bemerkungen über das Karibische Gebirge.*—Ergebnisse einer mit Unterstützung der Geographischen Gesellschaft zu Hamburg 1884–85, ausgeführten Reise von Dr. W. SIEVERS, 238 pp. Vienna and Olmütz (E. Hölzel)—Geographische Abhandlungen herausgegeben von Prof. Dr. A. Penck, Band III, Heft. 1. An extended notice was given in the February number (pp. 141–151) of another of the geographical memoirs published under the auspices of Dr. Penck. The present volume gives the geographical and geological results of a year's journey in the Cordilleras of Venzuela; a large geological chart accompanies the text.

6. *Krystallographisch-Chemische Tabellen* von Dr. A. Fock. 94 pp. Leipzig, 1890 (Wm. Engelmann).—This is a convenient series of tables giving for the successive groups of chemical compounds, both natural and artificial, the chemical formula, crystalline system, and axial ratio with the authority. It includes both inorganic and organic compounds.

7. *Copley Medal.*—The Copley medal of the Royal Society has been given this year to Professor Simon Newcomb for his researches in gravitational astronomy.

8. *Ostwald's Klassiker der Exakten Wissenchaften.*—Leipzig, 1890 (Wm. Engelmann). The recent numbers of this valuable series include the following:

No. 17. Abhandlungen über symmetrische Polyeder von A. Bravais (1849).

No. 18. Abhandlungen über den Speichel von C. Ludwig, E. Becher und Conrad Rahn (1851).

No. 19. Ueber die Anziehung homogener Ellipsoide: Abhandlungen von Laplace (1782), Ivory (1809), Gauss (1813), Chasles (1838), Dirichlet (1839).

No. 20. Abhandlung über das Licht, worin die Ursachen der Vorgänge bei seiner Zuruckwerfung und Brechung und besonders bei der eigenthümlichen Brechung des isländischen Spathes dargelegt sind, von Ch. Huyghens (1678).

OBITUARY.

JAMES CROLL, the eminent writer on geological physics, died in England, December 15th, 1890. The periods of his life and mental progress are well shown in the chronological sequence of his principal and best known works. With at first, a strong speculative tendency as shown in the "Philosophy of Theism," he soon engaged in more exact scientific investigations, and in 1864 appeared his essay, "On the Physical Course of the Change of Climate during the Glacial Epoch." This was followed by numerous papers, which in 1875 were incorporated in his well known work on "Climate and Time in their Geological Relations." An expansion of these ideas resulted in the publication of "Discussions in Climate and Cosmology," followed by "Stellar Evolution and its Relation to Geological Time." His last labors mark a return to the field of pure philosophy, and his final work on the "Philosophical Basis of Evolution" presents his most matured ideas in speculative inquiry.

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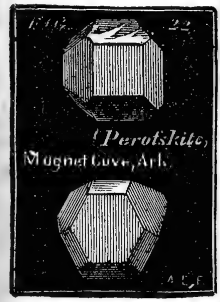

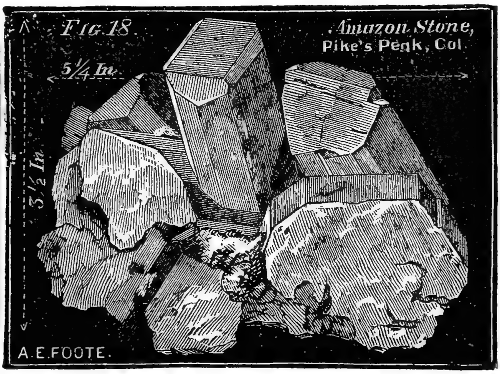

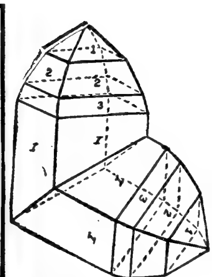

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ART. XXVIII.—*On Allotropic Silver;* by M. CAREY LEA.

Part II.—Relations of Allotropic Silver with Silver as it exists in Silver Compounds.

THE first part of this paper* was devoted to the examination of one of the well marked forms of allotropic silver,—the gold-colored. The blue form in its soluble and insoluble varieties will be more particularly described in a future paper. The subject at present to be considered is the relation existing between the allotropic forms of silver taken generally and silver as it exists in its compounds and more especially in the silver haloids.

It is a well established law that when a substance is capable of existing in two forms, of which one is a polymer of the other, the polymeric form possesses greater density and less chemical activity. Combination is usually accompanied with loss of activity, and the polymerization of a body consists in its combination with itself. When a substance is capable of existing in two allotropic forms and of being converted from the one to the other by pressure, the body resulting from pressure is always the more dense of the two and is a polymer of the first.† In the case of allotropic silver these laws appear to be verified. I have shown elsewhere that gold-colored silver has a specific gravity of 8·5, while that of normal silver is 10·5 to 10·6. The greater chemical activity of the gold-colored form is demonstrated by its greater affinity for oxygen, sulphur and

*In the March number, pp. 179–190.

† See examination by Spring of the effect of pressure, Ber. D. Ch. Ges., xvi, p. 1002, 1003.

the halogens. Also it is conspicuous by the remarkable facility with which it passes from the one state to the other. Spring, in the examinations above referred to, used pressures of many thousands of atmospheres. Allotropic silver is changed readily to normal by the mere pressure of the finger or by a temperature of 100° C.

One form of allotropic silver has the property of solubility in water. The solution of a solid in a liquid is often accompanied by change to a more simple molecular structure. Hitherto the only solvent known for a metal has been another metal, and the behavior of metals when so dissolved has been the subject of late years of very interesting examinations by several chemists. Ramsay* examined the lowering of the vapor pressure of mercury by other metals dissolved in it. Heycock and Neville examined the fall in the freezing point of metals, more especially of tin, caused by the solution in it of other metals.† Both of these investigations led directly to the conclusion that in the case of a dilute solution of one metal in another, the dissolved metal existed in the atomic form. (In each case a few metals gave exceptional results, but silver was not among these.) Tammann's investigations on the alloys of mercury led to precisely similar general deductions. Great weight attaches to conclusions supported in these several ways.

The fact that a metal in dissolving in another metal appears to assume the atomic form affords no positive proof that it does the same in dissolving in water. In fact the solution of a metal in water is something so new that we have little ground for argument by comparison. So far, however, as the above mentioned analogy may be considered to go, it rather tends to the view that the solubility of silver may be due to its having assumed a very simple and perhaps an atomic form. It may be said therefore that all considerations tend to show that the allotropic forms of silver taken as a whole have a more simple molecular nature than what I have described as the intermediate form, and that this again is more simply constituted than ordinary silver.

In the present case we have to consider three distinct forms, (1) allotropic, (2) intermediate, (3) ordinary silver. We notice that (1) can with the utmost facility and in several ways be converted into (2) and (3), and that (2) can always be converted into (3), but that *these transformations can by no possibility be reversed.* To convert ordinary silver into allotropic we must as a first step dissolve it in an acid: that is, *convert it from a polymerized to an atomic form*, and only from this atomic form can allotropic silver be obtained.

* R. Trans., 1889, p. 521, also Wiedemann, Referate 1889, p. 993.

† Jour. Chem. Soc., 1890, p. 376.—Nature, Jan. 1891, p. 262.

Bearing this capital fact in mind and considering the respective properties exhibited by the three forms of silver, it may be allowable to adopt as a working hypothesis the view that they may represent the three possible molecular forms of silver, viz: *atomic, molecular and polymerized.*

As silver in its compounds and in its saline solutions exists in the atomic form, it is easily conceivable that when it separates from such solutions by reduction, the atoms may or may not unite to molecules. Usually elementary atoms do so unite, but the phenomena of nascent action indicate that this union does not take place at the instant of separation, and it is at least conceivable that under particular circumstances this union may be prevented. In some cases no such union takes place. At least four metals exist in the form of vapor in the atomic state. Whether this state continues after condensation we do not know, but there is no impossibility but what such may be the case. Similarly allotropic silver may represent an atomic form: if this were so it should exhibit more active affinities for oxygen and the halogens than the ordinary form; also it should readily pass into the ordinary form. And these properties are undoubtedly exhibited by allotropic silver.

There is no branch of chemical statics in which our knowledge is so defective as it is in relation to the molecular constitution of solids and more especially of the metals. All that can be said is that in metals, as we ordinarily know them, this constitution is probably very complex, the molecules containing many atoms. When substances assume a variety of forms differing from each so much as do the forms of silver, we must either adopt a theory of the character now suggested or else we must suppose that the different forms are differently polymerized. To decide which is the most probable of these two views it is best to examine as to whether an analogy can be traced between these allotropic forms of silver and silver where it is known to exist in an atomic form, namely, in its compounds. For this comparison the silver haloids (and chiefly silver chloride) will be taken.

Action of Forms of Energy on Silver Haloids. Parallelism with Allotropic Silver.

It is a familiar fact that certain forms of energy, light especially, affect the silver haloids. In view of what has been already said as to the action of all forms of energy on allotropic silver, it seemed desirable to make a general examination as to their action on the silver haloids and thus to determine how far a parallelism could be traced.

It is to be observed that the action of different forms of energy on the silver haloids is apt to be partial: the influence seems to be antagonized by opposing and almost equally matched forces. Thus in the case of light, its tendency to condense the atoms of silver to molecules is largely counteracted by the strong affinity of chlorine for *atomic* silver. The action of high tension electricity as will presently be seen is similar to that of light in that it produces a visible effect. In the case of heat and of contact action on these silver haloids, it will be shown that there is at first a mere indication of effect, invisible to the eye, but readily brought out by the action of a reducing agent, as described below. The action of each form of energy seems to be almost counteracted by apposing affinities. But in every case action does take place and *always in a direction corresponding to the action of that form of energy upon allotropic silver.*

High tension electricity it is well known impresses sensitive films of silver haloids, which on development exhibit remarkable ramifications. When electric sparks are passed through paper on which a coating of silver chloride has been made, the point of passage of each spark is marked by a minute circle of violet color indicating a visible change, probably to a subchloride.

Mechanical force.—More than twenty years ago I noticed that by a slight pressure, an invisible effect, capable of development, could be impressed on silver iodide. Lines drawn with a glass rod or any other hard, neutral substance were reproduced. An embossed card pressed gently on the film, gave an image of all its details on development. These experiments were extensively repeated by others with concordant results.

I have recently repeated them with silver bromide with similar effect.

Heat.—To determine the effect of heat on silver bromide, pieces of bromide paper were placed in a desiccator (of course using inactive light) and heated to the extent indicated. For each piece so heated a corresponding piece cut from beside it in the same sheet was preserved, and these two pieces, that heated (after complete cooling) and that not heated, were placed side by side in an oxalate developer. Comparison between these developments indicated the effect of the heat. The following results were obtained.

A piece kept for 3 minutes at 145° C. was strongly affected and blackened quickly in the developer, the companion piece remaining white.

A piece kept for 15 minutes at a temperature commencing at 131° C. and ending at 136° was still more thoroughly affected than the foregoing, the longer exposure more than making up for the lower temperature. Companion piece remained white.

A piece kept for 8 minutes at a temperature 107° to 108° was distinctly but not strongly affected. Companion piece as before.

A piece kept for 17 minutes at a temperature of 100° to 102° was almost unaffected. A long and careful development brought out a faint difference between the piece so heated and its companion piece.

It was found that to obtain accuracy in determinations such as these, the paper must rest on a glass, and not a metal, shelf in the desiccator, as the metal shelf is always hotter than the air by which the thermometer is affected. In using a metal shelf, if the paper curled by reason of the heat, the part that rested on the shelf developed darker than that which was simply acted on by the air. By substituting a glass shelf this difference of effect disappeared.

The result of the foregoing and other experiments was that the effect of heat on AgBr commences at about 100° C., that up to 108° it is still slight and acts slowly, but that at 120° to 126° a strong action commences, which further increases as the temperature is raised. The analogy with allotropic silver is well marked.

It may at first seem strange that a temperature of 100° C. should produce a permanent change in a substance which will bear a high heat without decomposition, but the explanation lies in the presence of water in the former case. When silver bromide is formed in paper and dried in the air it still retains moisture. Even at 100° C. this moisture is not driven off. A silver haloid requires to be heated to a temperature between 130° and 140° for several hours before it ceases to lose weight. Therefore in all the foregoing cases moisture must have been present.

It remains to be shown that by a sufficiently long exposure to a moderate heat in the presence of moisture a visible decomposition results.

For this purpose silver chloride was precipitated with an excess of hydrochloric acid, after thorough washing was placed in a glass tube of about a centimeter in internal diameter and one-half a meter long, and was sealed up with a blast lamp. During all these operations the chloride was thoroughly protected from light. Five of six cubic centimeters of pure water were first added to the chloride. It was intended to exclude completely or almost completely the effect of pressure and to act on the chloride as far as possible by heat only, and for this reason a longer tube was used and one end only was immersed in the chloride of calcium bath, the other end remained cold throughout the operation.

The silver chloride formed itself into a compact plug and was forced by the steam which generated below it up to the

middle of the tube. This effect, though not intended, answered very well as the chloride was kept constantly under the influence of steam at about 100°. It soon began to darken and at the end of three or four hours all the lower part was violet brown, the upper part gray, the change taking place entirely through the mass. Some thin smears of silver chloride on the lower inside part of the tube were completely blackened.

On opening the tube next day there was no escape of gas. The water sealed up with the silver chloride had acquired a faint but distinct alkaline reaction showing that enough alkali had been dissolved from the glass to overcome any acidity arising from decomposition of the chloride. The water contained traces of alkaline chloride.

A similar examination was made with silver bromide precipitated with excess of hydrobromic acid and thoroughly washed with distilled water. The action of diffuse light on silver bromide is very different from that on silver chloride. A portion of that prepared as above mentioned changed in diffuse light very quickly from yellow to greenish yellow, but after that first change the alteration was extremely slow and in an hour had only reached to a dirty greenish gray. The action of direct sunlight was quite different; fifteen minutes' exposure changed the greenish gray to dark chocolate brown.

In the tube the silver bromide did not form a plug like the chloride but separated into balls which remained in the bottom of the tube. By keeping the chloride of calcium bath considerably above 100° C. the water in the tube was kept actively boiling: it condensed in the upper part of the tube and returned. Six hours of this treatment only brought the bromide to the same greenish color which it would have acquired by a few minutes' exposure to diffuse light.

The conclusion to be drawn as respects both the silver haloids is that they undergo actual decomposition by the action of moist heat, but that this effect is much more marked in the case of chloride than that of bromide.*

Chemical action.—Dilute sulphuric acid quickly changes allotropic silver to normal, and therefore if the parallelism which I have indicated really exists, marks made on bromide paper with dilute sulphuric acid should be capable of development.

The experiment was made by drawing characters on silver bromide with a glass rod dipped into sulphuric acid diluted with twice its bulk of water. After allowing the acid to

* Light and heat act differently on silver chloride Heat can not decompose it in the absence of moisture but light can. This was proved by an investigation made by the writer in 1889. in which it was shown that fused silver chloride poured into petroleum and exposed after cooling to the sun's rays was instantly blackened.

remain in contact for two or three minutes, the paper was immersed in running water and was washed for an hour or two.

On applying the oxalate developer nothing appeared. Feeling confident that effect must be produced, the experiment was repeated several times and the results were closely examined. On one specimen it was found that the characters had appeared, but reversed, that is, lighter than the ground which had darkened by the development being pushed. This at once gave a clue; it showed that traces of the acid adhered too strongly to be removed by washing and by locally checking the development, interfered with the reaction. Accordingly, next time after a very short washing, the paper was immersed in water to which a trace of ammonia had been added, and after ten or fifteen minutes' action the ammonia was thoroughly washed out. The result was striking: as soon as the developer was applied the characters which had been traced with acid came out strongly as brown marks on a white surface.

Cold sulphuric acid even undiluted is generally held to have no action on silver haloids, but it is well known that the hot strong acid decomposes them. The foregoing experiments leave no doubt that the cold dilute acid produces an initial effect invisible to the eye but revealed by greater tendency to give way under the action of a reducing agent. This action of the acid comes therefore exactly into line with that of light and heat. In all three cases an effect is produced inappreciable until a reducing agent is applied. But in all three cases the agent which produced this invisible effect is capable by continued action under favorable conditions of bringing about a visible change without the aid of a reducing agent.

Light.—The silver haloids in their sensitiveness to light, show an important relationship to that of allotropic silver. When for example silver chloride precipitated with an excess of hydrochloric acid is exposed to light, the darkened product contains apparently no metallic silver* (it is probable that the trace of silver given up to nitric acid may arise from the decomposition of a very small quantity of subchloride). However this may be the subchloride and not metallic silver is the essential product.

This has always seemed a very enigmatical result. Two combinations of silver and chlorine exist; the one very stable, capable of fusion without decomposition, the other so unstable that it can hardly exist isolated, and yet the stable compound is rapidly broken up by light, even by a weak diffuse light,

* In some (unpublished) experiments made some years ago to test this point, I found that silver chloride exposed for several days to strong sunlight under water, with frequent stirring up, and subsequent washing yielded only a trace of silver to strong cold nitric acid after a contact of an hour.

while the unstable compound resists many days' exposure to the strongest sunlight.

In examining the action of light upon allotropic silver (see Part I) an equally remarkable effect was described. Although all the other forms of energy applied readily and quickly convert allotropic to ordinary silver, light (at ordinary temperatures), fails to effect this change even by exposures lasting for several months. If we conceive that the atomic form of silver which exists in AgCl corresponds to the allotropic form, and that the more condensed form of subchloride corresponds to the "intermediate form," we shall obtain a reasonable explanation of the action of light.

The inability of light to carry the change which it produces in allotropic silver beyond the "intermediate form" exactly corresponds to its inability to carry the decomposition of silver chloride further than to subchloride or rather to photochloride. (It is understood that the silver chloride here spoken of is that which is formed by precipitation with excess of hydrochloric acid). This explanation appears to remove a real difficulty, and at the same time establishes a perfect parallelism between that action and the action of light on allotropic silver.

Although the foregoing study of the silver haloids was made for the purpose of fixing the relations which exist between them and allotropic silver, the results nevertheless have much interest in relation to the haloids themselves and place their nature in a somewhat new light. For it is shown that these haloids, though substances in some respects of very great stability have their equilibrium so balanced as to respond to the slightest influence, not merely of light, but of any form of energy, not receiving a momentary but a permanent impression which, though so slight as to be invisible, still greatly increases the tendency of the molecule to fall to pieces under the action of a reducing agent. Further, four of these forms of energy, light, heat, electricity and chemical action, when more strongly applied totally disrupt the molecule. One form of energy, mechanical force, though capable of producing the invisible effect makes an apparent exception in respect of this ability to disrupt. This matter is now under examination and it will probably be shown hereafter that the analogies are complete and without exception.

The same completeness holds with regard to the analogies which form a principal subject of this paper, namely, those existing between allotropic silver and the metal as it exists in the salts of silver. No other salts but those of silver show this wonderfully balanced equilibrium, sensitive to all forms of

energy. But allotropic silver also shows an almost exactly similar capacity to respond to the influence of energy in all its manifestations by undergoing changes of a like character.

The inferences to be drawn from the foregoing seem to be as follows. That silver may exist in three forms: 1st. Allotropic silver which is protean in its nature; may be soluble or insoluble in water, may be yellow, red, blue or green, or may have almost any color, but in all its insoluble varieties always exhibits plasticity, that is, if brushed in a pasty state upon a smooth surface its particles dry in optical contact and with brilliant metallic luster. It is chemically active. 2d. The intermediate form, which may be yellow or green, always shows metallic luster, but is never plastic and is almost as indifferent chemically as white silver. 3d. Ordinary silver. . . . Further, that allotropic silver can always be converted, either into the intermediate form, or directly into ordinary silver; that the intermediate form can always be converted into ordinary silver, but that these processes can never be reversed, so that to pass from ordinary silver to allotropic it must first be rendered atomic by combination, and then be brought back to the metallic form under conditions which check the atoms in uniting. That allotropic silver is affected by all forms of energy, and that this effect is always in one direction, namely, towards condensation. That the silver haloids are similarly affected by the same agencies. That a remarkable parallelism is noticeable between the two actions, especially if we take into account that in the haloids the influence of energy is to some extent restrained by the strong affinity which the halogens show for atomic silver. There is therefore reasonable ground to suppose that in the silver haloids silver may exist in the allotropic form.

Philadelphia, March, 1891.

Art. XXIX.—*The Phenomenon of Rifting in Granite;* by Ralph S. Tarr.

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In the granite at Cape Ann and elsewhere it is noticed that the rock splits most easily in certain fixed directions; and it is by taking advantage of these lines of weakness, that large regular blocks are easily split from their bed in the quarry. An expert quarryman knows full well just what may be expected of the granite and in making his calculation, the prime factor is the direction and strength of the "rift." In many places there are other lines of weakness along which the

granite easily splits; but these lines rarely exceed three and they are termed respectively "rift," "cut off" and "lift." The latter is generally more or less horizontal; the "rift" is the stronger and the "cut off" the weaker of the two nearly vertical lines of splitting.

During the summer of 1887, as an assistant to Professor N. S. Shaler,* I made a careful study of the jointing and other phenomena exhibited in the granite quarries at Cape Ann,† and in the course of these studies became interested in the phenomenon of "rifting." Later some slides were cut with the idea of determining if possible the nature and cause of this phenomenon.

The Cape Ann quarries exhibit "rifting" in every form of variation. There are no two quarries in which the "rift" has the same peculiarities and in which it has exactly the same direction. In fact in the same quarry as in the case of the Rockport Granite Company quarry, the rift changes completely in different portions of the large pit. Furthermore, in one case, the "rift" becomes weak and the "cut-off" changes to "rift" in the same quarry. The reason for giving these facts is to show that there is such decided variation that the idea of attempting to explain the phenomena on the theory of widespread and uniform disturbance is out of the question, at least since the granite came into anywhere near its present position. That there has been much faulting in the granite is plain upon the most cursory examination. It might be reasonable therefore to suppose that the phenomenon of rifting was produced early in the history of the granite, and that the present variation is chiefly due to faulting and contortion.

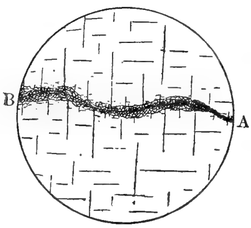
The so-called granite of Cape Ann is a hornblendic granitite containing orthoclase and some plagioclase feldspar, quartz, hornblende, a very little biotite and some magnetite. Under the microscope it is found that the quartz and feldspar show signs of much strain. There are tiny irregular faults and fault breccias (figs. 1, 2 and 3) both in the quartz and feldspar. With the naked eye the rift can be plainly seen, when it is strongly developed, to be a slightly irregular break cutting the rock and crossing quartz and feldspar alike. With the petrographical microscope, the crack appears quite irregular, and it can be frequently traced around quartz grains rather than directly across them. The line of breaking will often turn to one side in order to take such an easy path, and when crossing the feldspar it generally, in fact as far as my observations extend, always follows cleavage lines. Macroscopically

* While much of the detailed work was done by the writer, the general scheme and most of the conclusion must be credited to Prof. N. S. Shaler.

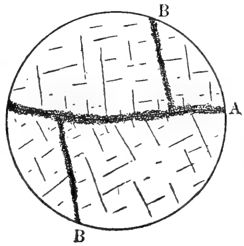
† See Ninth Annual Report U. S. Geol. Survey.

the line does not appear as a fault but simply a crack; but microscopically extremely minute faults can be detected, and the universally present fault breccia proves actual dislocation.

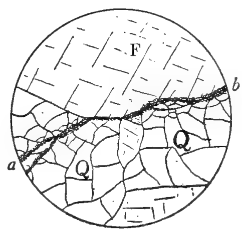
1.



2.

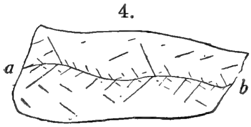


3.



The fault breccia is in reality a breccia, not as I at one time suspected a secondary development, for in several places I found pieces of feldspar only partially removed from the main crystal in such a way as to show the continuation of cleavage lines from the main piece into the dislocated portion. Along the fault lines in the margin of the feldspar, cleavage lines are frequently developed, and these tend to hide the fact that dislocation has actually occurred (fig. 4).

4.



Rifting is, then, dependent upon the thousands of minute dislocations which occur in every cubic inch of rock. The strains which produced these dislocations were of such a nature that three distinct sets were produced. I refer to Professor Shaler's article on Cape Ann in the Ninth Annual Report of the U. S. Geological Survey for 1887, for a full statement of the joint planes in the Cape Ann quarries. In this statement one of the most striking facts brought out, especially in the diagrams is that the joint planes follow distinct systems. There are three of these systems, one nearly horizontal and two vertical. The horizontal system is probably a contraction jointing formed during the cooling of the granite. These joints are irregular both in position and dip, are usually more or less dome-shaped, and lie one beneath another in concentric layers. The vertical sets of joints are much more regular, and are frequently perfectly straight cracks for several hundred feet horizontally and more than fifty feet vertically. They form with each other an angle several degrees less than a right angle. In almost any quarry these systems of jointing may be readily detected. Other joints occur, striking in almost every direction; but they are clearly accidental being most commonly diagonal across a block formed by the main joint planes, while the two main sets of vertical joints are the

result of one general cause, and in consequence follow a general law. In different portions of the Cape, the joints extend in different directions, but these variations may be readily explained on the supposition of faulting which has clearly been extremely common in this granite mass. In a number of cases the rift is found to follow the same general direction as the principal set of joints. This is particularly the case where the rift is well developed, as for instance in the quarries at Bay View.

In regard to the age of the rift, I can say very little that is definite. A careful study of 70 slides, cut from specimens of rock taken from the diabase dikes of Cape Ann, failed to show any sign of rift. From this it would appear that the rifting tendency was induced before the dikes were injected into the granite, but as the dikes mainly follow the joint planes, this is of little value in placing the age of the disturbance. There are some ragged dikes of quartz porphyry which were intruded before the jointing, but these show no signs of rifting. The evidence furnished by the dikes, however, is of little value for fine-grained rocks would not be likely to show evidence of microscopic faults. This fact is particularly well seen in the Cape Ann granite, in places where there are fine grained basic segregations. These segregations are as old as the granite, yet they show no rifting, although the surrounding granite has a very strong rift. The older dikes of quartz porphyries, and ragged diorite are very much faulted macroscopically, and very much changed in mineralogical composition microscopically, showing that there has been much motion and consequent alteration.

I suspect, although no evidence that I have been able to find conclusively proves it, that rifting and jointing are closely associated phenomena, and that the cause which produced one caused the other. What this cause was I shall not attempt to say, though plainly it was one of great extent and vast force. Between the almost microscopic rift and the joint plane hundreds of feet in linear extension, I have been unable to find any satisfactory gradation. Even the similarity in direction is not as striking as could be desired, to prove the connection. At Bay View, however, where the rift is remarkably strong, in some exposed places it has doveloped into many small parallel joints. These joints are about six inches apart; but if the rock is struck with a hammer it cleaves into many pieces parallel to these rift joints. Certain so-called "green seams" have been observed to pass out into rift-like breaks. These "green seams" are imperfect joints, lined with a thin layer of chloritic matter, which are not generally noticed by the quarrymen; but along which the rock is liable to split if

it is allowed to fall or is otherwise jarred. In one of these breaks I could plainly trace the passage from a distinct "green seam" to a rift-like break and then into unbroken granite.

From these facts I have been led to the supposition that before the injection of the dikes, the granite was subjected to contortion and pressure, which finally resulted in the production of rifting. Contortion would, it seems to me, produce just such a weakness in a hard, brittle, quartz-bearing rock. If, now, along some line of weakness in this partially rifted rock, the cohesion is overcome by the strength of the force which is compressing the mass, a joint plane would be formed. The probabilities are that the joint would be nearly parallel to the general rifted weakness, or else along the other line of weakness approximately at right angles to this. The third or horizontal set of "rift" planes, the so-called "lift" may have been a weakness inherent in the granite on account of the contraction of the mass during cooling. Subsequent faulting has displaced the granite, and broken it into such a number of pieces that we can no longer trace the general cause of rifting any better than we can that of jointing.

There is another possible explanation of rifting. There are in Cape Ann several hundred dikes, in many cases extending no doubt completely across the island (see Ninth Annual Rep. U. S. G. S., 1887—Shaler). The injection of this matter has expanded the bed rock several per cent more than its original bulk. This expansion must have been accompanied by a condition of great strain, perhaps enough to account for the breaking of the granite into its present rifted form. As the dikes for the most part follow the prevalent joint planes, these must have existed before the dikes were injected. This fact that the dikes follow the joints would explain the apparent similarity in direction of the joint and rift planes; and the absence of rift planes in certain places could be explained, either by the absence of dikes in that vicinity, or by some local peculiarity which relieved the pressure. The one fact which militates against this hypothesis is that there are no signs of rifting, and very little sign of strain in any of the earlier dikes which follow the joint planes, although they must have been subjected to great pressure during the injection of the later dikes. Altogether it seems to me more reasonable to suppose that the joints and rift phenomena are due to the same general cause, especially since there is a certain parallelism in direction between the two.

The inquiry then stands in rather an unsettled condition. The phenomenon of rifting is dependent upon certain microscopic breaks and even faults. There is a certain though not very definite parallelism between joints and rift and in some

cases the rift has actually developed into a joint. These facts indicate, though rather indefinitely, a common origin for the two phenomena though it is not impossible that the rifting phenomenon is subsequent in origin to the time of formation of the joint planes and possibly the result of the intrusion of the great number of dikes which cut the granite base of Cape Ann, and which must have brought about a condition of intense strain in the mass. A careful study both in the field and the laboratory fails to bring about a definite and satisfactory explanation of the cause of the phenomenon; and its settlement must await studies in other regions where dikes are less abundant.

Aside from the economic value of the rifting tendency there is a geologic effect of considerable importance dependent upon it. It was noticed in the study of the Cape Ann region that certain of the bowlders in the morainic drift had a tendency to crumble while others had no such tendency. This crumbling has gone so far that glacial bowlders which at the time of their transportation must have been solid and in a measure fresh, have, since the end of the glacial period, completely decayed to a crumbling mass of gravel. All stages in this decay may be seen on the island of Cape Ann. At first it was thought that this was the result of some chemical weakness in the rock, but a microscopic examination proved that the weakness was not chemical but mechanical. Whenever the rift is strongly developed the rock has the tendency to decay along the rift breaks; and at places, notably at the Bay View Quarry along the line of the railway in a fresh cut not more than fifteen years old, the decay along the line of the rift has not only developed well marked joint-planes but has begun to crumble the granite into gravel. A better case than this even is illustrated in the photograph (Plate LI, 9th Annual U. S. G. S.), where several large bowlders of degradation have resulted through the agency of the weather acting along the rift planes in post-glacial times. Thus the phenomenon of rifting is, in the Cape Ann region at least, an important geological agent because of the aid which the lines of mechanical weakness furnish the agents of disintegration. Prior to our investigations, so far as I know, no notice has ever been taken of the phenomenon of the rift, yet I have no doubt it will be found to be of equal importance in many other localities than the one studied.

ART. XXX.—*The Redrock Sandstone of Marion County, Iowa*; by CHARLES R. KEYES.

[Read before the Iowa Academy of Sciences, September 5, 1890.]

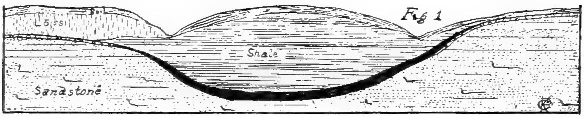
THE sandstone of Redrock, in Marion County, Iowa, has recently come into prominence as a building stone; and is now used more or less extensively throughout the State for the better class of architectural work. Long ago this rock was utilized in various structures at DesMoines and elsewhere, but the method of obtaining it, by blasting, shattered the stone so as to render it almost worthless for building purposes. It soon fell into disrepute and for more than thirty years has not been used except for unimportant local masonry. Recently extensive steam sawing apparatus has been brought in and the stone removed in huge blocks before reduction by further sawing to sizes required. In this way the sandstone is not injured as when the blasting method was in vogue. The resistance to crushing power of the better portions of the rock is now considered to be nearly equal to any in the country.

The Redrock sandstone has long attracted popular attention. The bright vermillion cliffs rise to a height of one hundred to one hundred and fifty feet above the water surface of the DesMoines river. The red coloration of the rock is, however, local, merging laterally and downward into a yellow or buff color. The formation has a known geographic extent of at least twenty miles and probably stretches out much farther. At Redrock cliff the stone is, for the most part, massive; but rather soft and thin-bedded above. At this place it is a very fine grained and homogeneous sandrock, some portions even affording excellent material for grindstones. But southwestward, and at Elk bluff two miles below, the sandstone passes into a fine-grained, ferruginous conglomerate. The dip is everywhere to the south and west; and, at a short distance above the quarry just alluded to, the inclination is very considerable. A mile beyond, the sandstone has disappeared completely and the section shows only shales and clays. The space between the latter exposure and the last known outcrop of the sandstone is perhaps half a mile, the interval being hidden by Quaternary deposits down to the water-level. The abrupt change in the lithological characters of the rocks in so short a distance has been mentioned by Owen* and Worthen,† but the true explanation is entirely different from the suppositions of those writers.

At Redrock quarry the strata overlying the sandstone are disclosed as shown in figure 1, the horizontal and vertical scales

*Geology Minn., Iowa and Wisc., 1854. † Geol. Iowa, 1858.

being the same. The full thickness of the sandstone is not represented in the cut. The upper limit is very uneven and



paved everywhere with rounded water-worn bowlders and pebbles, derived from the sandstone itself. A gray fire-clay covers this pavement and upon it rests a coal bed having a thickness of six feet centrally, but rapidly thinning out laterally in both directions to a very unimportant, scarcely recognizable, bituminous seam. Northward, or at right angles to the face of the section, the coal is thicker. Superimposed upon the coal are drab and ash-colored, clayey shales, having an exposed thickness of thirty feet, but which are manifestly much more extensive. From a consideration of this section, then, it is clear that before the superimposing coal seam was formed the vast sand bed had been raised above the surface of the waters, consolidated, and was then subjected to considerable denudation. In a small gorge or ravine, excavated in the sandstone, the carbonaceous material was deposited as the land was again being submerged. Immediately to the north of the section represented in the figure (which faces the south), the corrasion was much more extensive, as is shown by the rapid inclination of the axis of the gorge in that direction; so that the section is actually across a tributary ravine opening into a large basin in which the coal is now mined in large quantities. The inference is, then, that the abrupt disappearance of the vast bed of sandstone in such a short distance as half a mile above the quarry, where it has an exposure of more than one hundred feet, is not due wholly to the inclination of the stratum, but is the result of great erosion in that direction, previous to the deposition of the shales and clays; and that the massive sandstone really formed a bare hill of considerable height against which the subsequent deposits were laid, when the conditions for such a change occurred.

Three miles down the river from the Redrock quarry is another instructive exposure. A small but deep ravine divides the section. On the left is the concretionary limestone—the last outcrop of the St. Louis in Central Iowa to be noted in the ascent of the DesMoines river. At this place it rises in a low arch about fifteen feet above low-water. Overlying it are marly and somewhat sandy clays or shales which have a vertical exposure of sixteen feet. The strata dip 10° to the

eastward. On the right a fine-grained ferruginous conglomerate—an extension of the Redrock sandstone—rises in vertical cliffs to a height of one hundred and fifty feet. The inclination is 5° to the westward; but the dip is perhaps even greater to the southwest. The strata are visible down to the water's edge. The direct line of contact between the arenaceous and calcareous beds is not shown, as the detritus brought down by the streamlet and the alluvial material deposited at its mouth by the DesMoines during high water completely conceals the stratified rocks for several yards on each side of the entrance. In his ascent of the DesMoines river in 1852, Owen observed the same exposure and thought that it indicated a fault of one hundred and fifty feet or more. It is more probable, however, that the case is one similar to that exhibited at the Redrock quarry; and that the limestone area at the time of deposition of the sandy material was a slowly sinking island or low promontory, which was eventually completely covered by the arenaceous deposit.

At all appearances here was an extensive sandstone formation, with a maximum thickness of more than one hundred and fifty feet, lying unconformably upon the St. Louis limestone and with coal-bearing strata imposed unconformably upon it. At first it was thought that the sandy member represented shore or estuary deposits of the Kaskaskia sea. Such, however, was found not to be the case. A few miles below, exposures were observed showing fully seventy-five feet of dark sandy, clayey and bituminous shales between the sandstone and the concretionary limestone. The shales carry at least two workable seams of good coal, one of which attains a thickness of five to seven feet and has a very considerable geographical extent.

As exposed along the DesMoines and Skunk rivers the upper portion of the St. Louis strata is made up of blue and gray fragmentary limestone, overlain usually by several feet of gray, highly fossiliferous, marly clay. The most characteristic and widely distributed fossils are: *Spirifera Keokuk* Hall, *Pentremites koninckiana* Hall, *Athyris subquadrata* Hall, *Zaphrentis spinulifera* Hall and *Productus marginicintus* Prout. There are also a number of monticuloporids, terebratulæ, lamellibranchs, and a few gasteropod and trilobite remains. In many places the St. Louis formation exhibits considerable surface erosion due to subaerial agencies that acted before the deposition of the lower Coal-measures; and the soft marly upper member has been largely removed. The superimposing strata thus rest sometimes on limestone, sometimes on marl.

The detailed stratigraphy of the dark, coal-bearing shales immediately beneath the Redrock sandstone is exposed a short distance below the village of Redrock. The coal seam is from four to five feet in thickness; and is overlain in places by a few feet of alternating sandy and clayey shales. In the sandstone directly over the coal are vast numbers of finely preserved vegetable remains: huge lepidodendrids and sigillarids of eight, ten or more species, massive calamites and delicate ferns, abundant but not packed together in confused masses.

The recent observations have cleared up many of the hitherto doubtful points concerning the geological history of the Redrock sandstone. It is not the basal member of the Coal-measures, as was regarded by Worthen; nor is it a shore extension of the Kaskaskia limestone; neither is its geographic extent as limited as had been supposed. Twenty miles to the southeast of Redrock a sandstone of great thickness, having identical lithologic characters and with a similar stratigraphical position is believed to be its extension southward. And it may also rise a few feet above low-water in the northwestern corner of Marion county. The most interesting consideration in regard to this Redrock sandstone is the fact of its considerable elevation above the surface of the sea and its subjection to subaerial erosive agencies for a long period of time before submergence again took place. During that interval the great thickness of sandstone probably was almost entirely removed in places.

The southern prolongation of the formation yet remains to be made out and its geographic limits eastward and westward from Redrock village more definitely determined, for there is every reason to believe that it extends beyond the boundaries at present known.

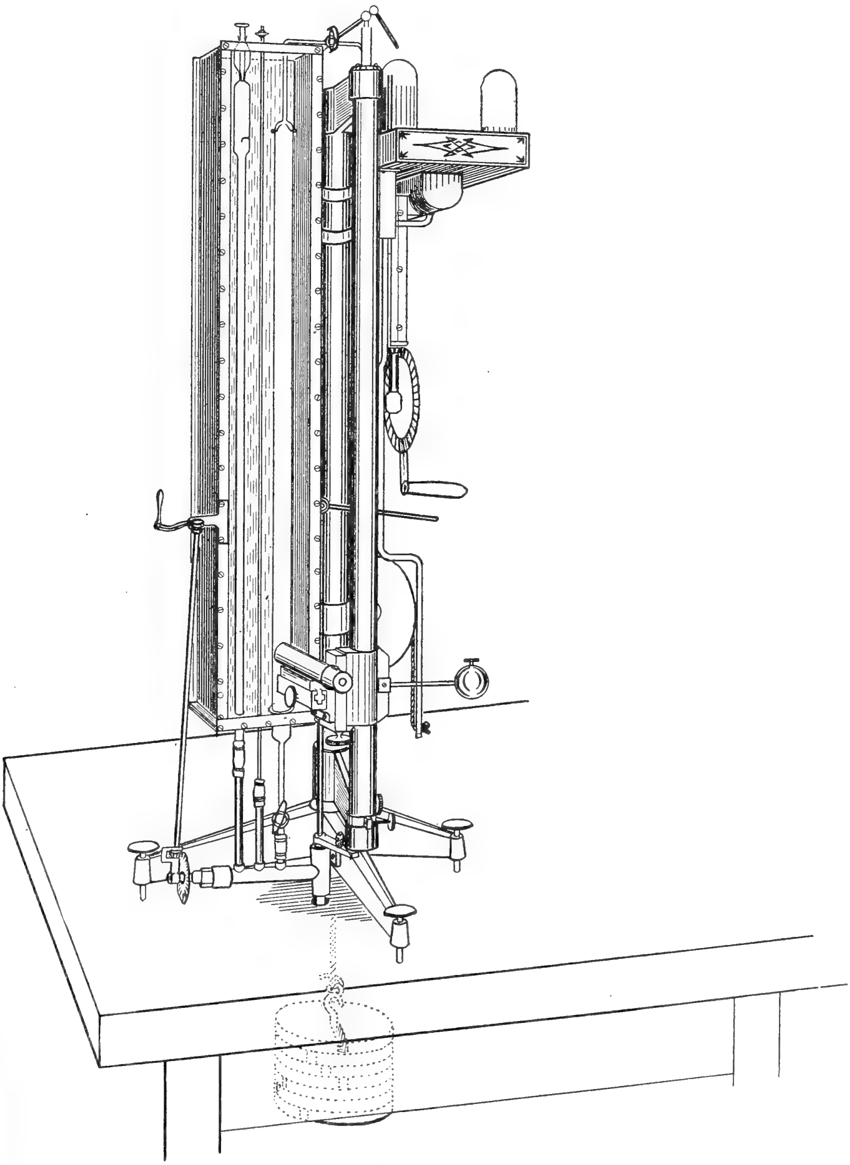
ART. XXXI.—*The Volumetric Composition of Water*; by EDWARD W. MORLEY.

[Continued from page 231.]

Apparatus for accurate measurement of volumes of Gases.—My measuring apparatus has finally become rather elaborate. It is shown in fig. 3. It is mounted on a stone pier, independent of the floor of the room in which it stands. The eudiometer and measuring tube ends above in a stopcock and recurved tube whose end is seen to emerge inside the left hand gas jar in the cistern. The stopcock is manipulated by means of a metal shaft and long handle, seen at the top of the column which carries the reading microscope. At the bottom

of the eudiometer is a glass stopcock of large bore intended to facilitate the washing out of the eudiometer after an analysis.

3.



For this purpose the glass plug of the stopcock is withdrawn and a duplicate plug inserted in which there are such connec-

tions that the part below the stopcock is shut off, and an opening is left between the eudiometer and the outside of the apparatus. By connecting the top of the eudiometer to an air pump, aqua regia or potassium hydroxide can be drawn into the eudiometer; then by connecting the bottom of the eudiometer to the pump, distilled water can be drawn in at the top. In this way the tube was kept so clean that carbon dioxide was formed only twice, when this washing was omitted; accurate reading of volumes were also facilitated. Below the glass stopcock, the eudiometer is connected by a rubber connector, to a steel tube screwed into an iron stopcock. The key of this stopcock is prolonged upwards some four decimeters, and ends in the handle seen just above the reading microscope. A small wheel imperfectly seen under the reading microscope carries a series of stops of which any one can be brought into position so as to arrest the opening of the stopcock at a determinate point. This stopcock governs the admission of mercury from the movable reservoir carried vertically by an apparatus placed on a table to the left. The iron stopcock has three steel tubes which are connected, one to the eudiometer as said before, the others to the two pressure tubes; the smaller of these is an auxiliary, used for all rough measurement, so as to reserve the other for the final accurate measurement. This tube is shut off from connection with the other tubes by a piston valve whose motion is produced by the geared wheels seen at the left of the iron stopcock. Its vacuum was easily kept unimpaired for months, as was proved by repeated determinations. But further, this piston valve also served as a micrometric adjustment of the level of the mercury in the eudiometer and pressure tubes. The use made of this will be mentioned below, and it contributed greatly to the accuracy obtained. These three tubes were enclosed in a box with glass front and back, and filled with clear water kept stirred by a current of air. The eudiometer is secured into a brass plate which is ground water-tight to the bottom of the box: on removing a clamp, the eudiometer can be lifted out of place if necessary, and can be replaced without a variation of its level amounting to the hundredth of a millimeter. It was convenient to compute the measured volumes of gases by means of an interpolation formula whose constants depended on the relative levels of fiducial marks on the eudiometer and pressure tubes, and constancy of this relation even after removing the eudiometer, was highly desirable. The pressure tube was provided with a fine screw motion by which it could be adjusted vertically while in position and filled ready for use.

The recurved tube at the upper end of the eudiometer serves for the introduction of gas into the apparatus. The

cistern containing the jars of gas is capable of the motion required to bring the open end of this recurved tube inside of the jar *ab* and to its top. When the cistern is in its highest position, the recurved tube is wholly contained within the well seen under the cistern, and the cistern can be moved vertically by a distance equal to the height of the tallest jars used. It is fitted with sliding ways, counter-poised, and moved by a screw; by means of a multiplying gear, its motion can be made as rapid as is convenient; by means of the adjustable counterpoise, the cistern with its thirty-five kilograms of mercury can be moved up and down and placed accurately at the required level with ease and safety. In the center of the cistern is a well for filling the jars used: the rest of the bottom is inlaid with a smooth surface of slate. Care was taken to have no crevices in which air could be entangled, from which perhaps it should rise into a jar of gas. The mercury was always kept as much as three centimeters deep, to lessen the probability that gas in the jars should be contaminated by diffusion between the walls of the jar and the mercury in contact with them. But the danger of this contamination is very slight. I left two jars of hydrogen standing in the cistern for eleven weeks, after which time I was unable to detect any contamination. The reason of this, so different from the result obtained by Faraday,* is probably the great care taken in filling the jars with mercury. The jar was always put entirely under the surface of the mercury while it was closed with a glass plate, so that no dust from the free surface of the mercury could get to the inside of the jar.

The vacuum in the pressure tube was obtained by exhausting the tube from above while the bottom was closed, then admitting mercury till it rose above the glass stopper at the top of the tube; during the exhaustion, the stopper was loosely in place, and was in the vacuum. When the stopper was covered by mercury, it was forced into place; a drop of water had previously been put in the upper part of the pressure tube. In the pressure tube were two Jolly points; of which sometimes one was used, sometimes the other, an interpolation formula having been computed for each of the two systems of pressures measured by the mercury when brought to one of the points. The vacuum in the pressure tube was often measured or rather, the real zero of pressures was determined by producing a good vacuum in the eudiometer, bringing the mercury in the pressure to one of the Jolly points, and observing the level of the mercury in the eudiometer; this level was the zero from which pressures were counted, and could be

* Annals of Philosophy, [II], vol. xii, p. 389, 1826; Poggendorff's Annalen der Physik, vol. viii, p. 124, 1826.

verified as often as desired, and did not change during the series of experiments.

The measurement of the reduced volume of a gas is effected by adjusting the apparent volume till the mercury in the pressure tube stands at one of the Jolly points, and measuring the level of the mercury in the eudiometer. This reading determines the apparent volume, and the difference between this reading and the reading of the zero point gives the pressure under which the gas is measured. A convenient interpolation formula reduces the computation to the addition of a constant to the reading, taking the doubled logarithm of the sum, and adding a logarithmic constant.

The measurement of the level of the mercury in the eudiometer is made by means of a reading microscope. This is carried on a cylinder supported on the frame work of the instrument, and provided with a tangent motion. On this cylinder slides a piece which can be tightly clamped, and which carries ways on which the microscope can be moved vertically by a micrometer screw. When the microscope is made to give distinct vision of a scale engraved on the eudiometer, the terminal lines of an eye-piece micrometer are made to agree with two successive millimeter divisions of the scale. As these are but the three hundredth of a millimeter wide, the coincidence can be made accurately. When coincidence is secured, the microscope is made to give distinct vision of the meniscus and the illumination arranged. When the mercury is now made to coincide accurately with one of the Jolly points in the pressure tube, the reading of the fraction of a millimeter by which the mercury in the eudiometer stands above a millimeter division of the scale is accomplished in a few seconds. Great care was taken in the calibration of the eudiometer. For this I fused to the end of the recurved tube, mentioned before, a further tube opening downwards. Through this air-free water was introduced into the eudiometer. The mercury reservoir being raised, mercury was admitted by opening the iron stopcock against the proper stop. Water then began to drop from the added tube. The rate of admission of mercury must be so slow that the amount of water left adhering to the inside of the eudiometer is small, and is nearly constant from one experiment to the next. Three hours for the admission of eighty centimeters of mercury gave concordant results. When the mercury reached the lowest point to be calibrated, the iron stopcock was closed, and the level of the mercury and the temperature of the water determined. The tube from which the water had been dropping was wiped in a constant manner, and a tube put in place to collect the water which now issued on opening the iron

stopcock. When the mercury rose to the next standard point, level and temperature were measured, and another tube placed to collect water, while the water already issued was weighed. True volumes at zero were computed from the weights and temperatures observed. The calibration was made four times; I give the values found for the points at which oxygen and hydrogen were measured in the experiments, and the differences between the mean and the several determinations. It will be seen that the mean error of a single determination of volume is five cubic millimeters. A tube was previously cali-

Scale Division.	Volume found.	Errors (cubic millimeters).			
		1.	2.	3.	4.
600	184·323	0	12	− 7	− 4
625	191·849	−3	− 4	4	4
650	199·442	1	− 2	10	−10
675	207·082	7	−15	2	7
700	214·766	−1	3	5	− 7
725	222·460	1	4	−10	5
750	230·132	−1	− 3	− 1	5

brated with a mean error only three fifths as much; but it broke during the first experiment. The sky was so cloudy while this the present tube was calibrated that illumination was defective, and work very trying. But in the determination of the volumetric composition of water, any slight errors, either in the calibration of the standard points, or in the interpolation at intermediate points, was nearly eliminated by a proper distribution of the points used in the measurements.

Since, in my way of manipulating, the gas, scale, mercury, and eudiometer are all at the same temperature, the effects of the expansions of all were taken into account in one factor, which moreover, was determined for the actual degrees of the thermometer used.

In measuring the volume of a quantity of gas in the eudiometer, the mercury in the recurved capillary tube was brought to a certain mark. The level of the mercury in the eudiometer was so adjusted that when the pressure tube was opened, the mercury in it would stand near one of the Jolly points. Then the level of the reading microscope was adjusted, and the meniscus was brought into focus. During this time, the water surrounding the eudiometer was stirred by a current of air. When everything was ready, the current of air was shut off, and the piston valve slowly moved till the mercury exactly coincided with the Jolly point. Then, within five or ten seconds, the thermometer was read and the fraction of a

millimeter shown in the reading microscope was determined. The water was then again stirred, the adjustment at the Jolly point, and the reading of the thermometer and of the reading microscope was repeated. By means of the fine adjustment of the level of the mercury which has been mentioned, the adjustment at the Jolly point could be made within the five hundredth of a millimeter, and it could be repeated as many times as was desired. It was also possible to make the final adjustments, and the two readings, within a time too short for any change of temperature in the gas to be measured. Readings of temperature were to the two hundredth of a degree, and of level to the two hundredth of a millimeter. To show what degree of accuracy can be obtained by an apparatus such as is here described, including both errors of readings and errors of transfer due to bubbles of gas entangled in the capillary tube, I put a quantity of gas in a jar in the cistern, transferred it to the eudiometer and measured it, transferred it back to the jar and measured it again, and so ten times. I give the reduced volumes so found. From this it seems that the probable error of measurement, not including errors of calibration, are something like a seventy-thousandth part of volumes like those used in the determinations of the volumetric composition of water. I also found the mean error of a single measurement by computation from the mean error of a determination of the ratio sought. In this way, it seems that the mean error of a single measurement of such a volume as one hundred and fifty or two hundred cubic centimeters is its fifty thousandth part. This value *includes* the errors of calibration as far as they affect a determination of the ratio. The direct determination of mean error of measurement was made under selected conditions as to illumination and health which could not be secured in the determinations of the ratio.

Repeated measurements of the same volume of gas, transferred to jar after each measurement.

210·81^{cc}	210·805^{cc}
210·815	210·815
210·815	210·81
210·815	210·81
210·815	210·81

Determination of nitrogen contained in the hydrogen used for determination of the volumetric composition of water.—The parts *p*, *q*, *r*, were exhausted, filled with hydrogen, from *n*, and again exhausted. The pressure of the gas in *n*, was then measured by means of *m*, and its temperature by thermometers at *n*. From this, with the known volume of *n*, and

its connections, could be computed the reduced volume of the gas in *n*; then *r* was heated, and the valve *o* was opened. When about a liter of hydrogen had been taken from *n*, *o* was shut, and the volume remaining was determined. The heating of *r* was continued till the gas remaining was reduced to some such volume as ten cubic centimeters, when *r* was cooled, and the gas was extracted by the Sprengel pump. A suitable excess of oxygen was extracted from its store, the two gases were measured, mixed, exploded, and the residue measured. From this was computed the amount of hydrogen found by analysis, whence was learned by difference the amount of nitrogen which was originally contained in the volume known to have been extracted from *n*.

To illustrate by an actual experiment: In *n*, before extracting any hydrogen, the temperature and pressure were 766·5 millimetres, 20·5 degrees; after, 662·0 millimetres and 20·9 degrees. Hence it was computed that 823 cubic centimeters had been admitted to *r*. When *r* was cold, the hydrogen remaining was extracted, and transferred to the apparatus shown in fig. 3, and found to be 6·722 cubic centimeters at standard temperature and pressure. Oxygen was added, and the sum found to be 17·101 cubic centimeters. After explosion there remained 7·019 cubic centimeters. Hence the hydrogen found in the 6·722 cubic centimeters taken for analysis was 6·721 cubic centimeters. A duplicate analysis agreed well with this; so that this hydrogen was practically free from nitrogen.

Determination of the volumetric composition of water.—Two jars of hydrogen were extracted from *n* without heating *r*, and a jar of oxygen from the store of oxygen. I measured a convenient volume of hydrogen; for ease of explanation, suppose it was 180 cubic centimeters. About 120 cubic centimeters were transferred after measurement to a jar in the cistern, and the other 60 to a second jar. Then a volume of oxygen either a little smaller or a little larger was measured; suppose it was 175 cubic centimenters. After measurement, it was transferred to three jars, 60 cubic centimeters to the jar having 120 of hydrogen, 60 to the other jar of hydrogen, and 55 to a small graduated jar. Another volume of hydrogen was next measured, say 179 cubic centimeters. One-third of this was put into the jar into which the smaller quantity of hydrogen had been put before, and the remaining 120 cubic centimeters were left in the eudiometer.

It will be noticed that the three measurements are made at as nearly the same point as is consistent with the fact that there must be a slight excess of either one gas or the other. It would probably have been better to have made the three

volumes as nearly equal as possible, and then to have measured a small excess at the point at which the excess was to be measured after the explosion. But this was not thought of in time As it was, errors of calibration could have no great effect; but they were further made of still less effect on the final mean in two ways. In some experiments, the hydrogen was put in excess, and in some, oxygen; if in two such experiments the sum of the two gases were the same, the points of measurement of oxygen and of hydrogen would be interchanged, and the errors of calibration would produce contrary effects. Again, the amounts of gas taken were increased from time to time, so that all points from 63 to 75 centimeters were used, by which also accidental errors in calibration were rendered of small influence on the result.

The measured gases were now ready for explosions in fractions. Explosions were always made in the presence of a large volume of inert gas. The ratio of explosive gas to inert was varied within somewhat wide limits, and the same ratio was preserved throughout all the explosions of a given experiment. Suppose that in a given case the ratio desired was that of four to one. To the 120 cubic centimeters of hydrogen left in the eudiometer were added 30 from one of the jars containing hydrogen and oxygen. After this was exploded, a like volume was added again, and so on, till all the gas previously mixed had been consumed. There would still be 120 cubic centimeters of hydrogen in the eudiometer. To this was now added eight cubic centimeters of oxygen from the small graduated jar. The two were mixed by letting mercury drop through the eudiometer, and were exploded. A smaller computed volume of oxygen was added and mixed for the next explosion, and so on, till all the oxygen was finally exploded in presence of fifteen times its volume of hydrogen. But when oxygen was to be finally in excess, a variation was made a little before the last explosion, by adding small quantities of hydrogen to an excess of oxygen in the eudiometer; up to this point, hydrogen was kept in excess. It is obvious that the last explosion of the series is the critical one on whose completeness accuracy depends; sufficient attention was given to this matter.

After the explosion was completed, it cost some trouble to put the eudiometer into condition for good measurement, because so much water had accumulated in it. Then an excess of oxygen or of hydrogen, as the case might be, was added, the mixture was exploded and the residue was measured. From this was computed the amount of nitrogen in both gases taken together; subtracting the nitrogen known to exist in the hydrogen according to the previous experiment the remainder was the nitrogen in the oxygen used. The ratio of the volumes

of hydrogen to oxygen in water could then be computed. As to the chemistry, consumption of oxygen by oxidation of mercury or of fat, and the possible production of hydrogen dioxide had to be considered.

When mercury is oxidixed in the eudiometer, it is by the oxidation of fine globules on the walls of the eudiometer. In mixing the last third of the oxygen with hydrogen, it was convenient to let a current of mercury run down through the eudiometer; which covered its walls with mercury. In three experiments, some of this mercury was oxidized; two experiments were lost. In the other, it was found possible to reduce the oxidized mercury by a managed explosion, so that the water produced was perfectly clear, as it was in all the other experiments.

There was no carbon in my gases before they were measured. In two experiments, when the eudiometer had not been cleaned, carbon dioxide was produced. This must have come from fat on the walls of the eudiometer forced down by the current of mercury which mixed the oxygen and hydrogen. Since the composition of the lubricant was well enough known, it was possible to add to the oxygen used in producing carbon dioxide, the amount used in the combustion of the hydrogen of the fat, and so deduce the value of the ratio sought. As to hydrogen dioxide, in the absence of sufficient knowledge of what might take place in an excess of oxygen, hydrogen was kept in excess till nearly the end of the series of explosions.

To illustrate by an actual experiment, I will give all details of experiment number 6. The first column gives the temperatures, the second the readings of the scale of the eudiometer, the third gives the reduced volume of gas deduced from each measurement, and the fourth gives the adopted mean, with the name of the gas measured.

Temperature.	Pressure.	Volume reduced.	Means.
19·87	688·75	174·333	
19·89	688·76	174·326	174·33 hydrogen.
20·26	680·62	169·954	
20·29	680·65	169·947	169·95 oxygen.
19·44	685·45	172·910	
19·47	685·47	172·905	
19·59	679·98	172·920	172·91 hydrogen.
20·18	137·92	7·797	
20·54	138·08	7·805	7·80 residue.
20·73	255·54	25·271	
21·78	256·02	25·269	25·27 residue and oxygen.
21·80	187·06	13·829	
21·76	187·05	13·830	13·83 residue 2.

1. $\frac{2}{3}$ (25·27 − 13·83) = 7·62^{cc}, hydrogen in residue 1.
2. 7·80^{c} − 7·62^{c} = 0·18^{cc}, nitrogen in residue 1.
3. 0·18^{cc} − ·00 = 0·18^{cc}, nitrogen in oxygen used.
4. $\dfrac{174{\cdot}33 + 172{\cdot}91 - 7{\cdot}62}{169{\cdot}95 - 0{\cdot}18} = 2{\cdot}00047$; ratio sought.

The experiments made divide themselves into groups according to the purity of the gases used. In some, both gases contained nitrogen, in some, only the hydrogen, in some only the oxygen, and in some, both gases were pure; in some carbon dioxide was produced, although both gases were pure. I give in full the quantities measured or the quantities computed from them, in the case of the first experiment of each of these groups; but I selected the eighteenth experiment, rather than the seventeenth, so as to include one in which there was an excess of oxygen.

Number.	Pressure.	Temperature.	Hydrogen taken.	Oxygen taken.	Residue.	Hydrogen in residue.	Oxygen in residue.	Nitrogen in hydrogen.	Nitrogen in oxygen.	Carbon dioxide formed.	Oxygen consumed.	Amount to be subtracted from hydrogen	Amount to be subtracted from oxygen.	Hydrogen used.	Oxygen used.	Ra io.
	cm	°	cc	cc	cc	cc	cc	cc				cc	cc			
1	64	22	307·89	150·03	8·29	8·015	---	·11	·165	---	--	8·12	·165	299·77	149·865	2·00027
2	64	22	307·29	149·28	8·68	8·57	---	·11	·00	---	--	8·68	·00	298·61	149·28	2·00033
4	66	20	325·36	156·21	13·36	13·21	---	·00	·15	---	--	13·21	·15	312·15	156·06	2·00019
14	72	23	383·30	185·70	11·87	11·87	---	·00	·00	---	--	11·87	·00	371·43	185·70	2·00016
18	75	25	407·98	205·71	1·73	----	1·66	--	---	·065	·09	·00	1·75	407·98	203·96	2·00029

In the following table I give the approximate temperature and pressure at which the hydrogen and oxygen were measured in each experiment, the amounts of impurities found in each gas, and the amounts of hydrogen and oxygen consumed in the explosion, with the ratio thence deduced. The pairs of determinations which are bracketed together were made one immediately after the other of the pair, with the same stores of gas extracted at the same time, and as nearly as possible under the same conditions, except that different gases were in excess. This will explain why the amounts of impurities found in the oxygen used should show such agreement. The oxygen used in the experiments from the fourth to the twelfth was obviously undergoing slow admixture with air; which was suffered to continue, in order to see if the presence of nitrogen affected the ratio found. After a while, the crack in a glass tube which had shown itself was closed by fusion.

Number.	Temperature.	Pressure.	Nitrogen in hydrogen.	Nitrogen in oxygen.	Carbon dioxide produced.	Oxygen consumed.	Hydrogen consumed.	Oxygen consumed.	Ratio.	Gas in excess.
	°	cm	cc	cc						
1	22	64	·11	·165	----	----	299·77	149·865	2·00027	hydrogen.
2	22	64	·11	·00	----	----	298·61	149·28	2·00033	hydrogen.
3	19	66	·12	·00	----	----	316·45	158·205	2·00025	hydrogen.
4	20	66	·00	·15	----	----	312·15	156·06	2·00019	hydrogen
5	20	66	·00	·15	----	----	325·36	162·67	2·00012	oxygen.
6	20	70	·00	·18	----	----	339·62	169·77	2·00047	hydrogen
7	20	70	·00	·18	----	----	347·24	173·60	2·00024	oxygen.
8	20	72	·00	·31	----	----	364·58	182·28	2·00011	hydrogen
9	20	72	·00	·31	----	----	386·65	193·31	2·00016	oxygen.
10	22	72	·00	·72	----	----	381·85	190·92	2·00005	hydrogen.
11	22	72	·00	·82	----	----	389·79	194·87	2·00026	oxygen.
12	22	73	·00	·82	----	----	395·75	197·85	2·00027	hydrogen
13	23	71	·00	----	----	----	372·09	186·01	2·00038	hydrogen.
14	23	72	·00	·00	----	----	371·43	185·70	2·00016	hydrogen
15	23	72	·00	·00	----	----	383·30	191·62	2·00031	oxygen.
16	26	73	·00	·00	----	----	383·51	191·74	2·00016	hydrogen
17	26	73	·00	·00	----	----	392·58	196·27	2·00021	oxygen.
18	25	75	·00	·00	·065	·09	399·74	199·85	2·00020	hydrogen
19	25	75	·00	·00	·065	·09	407·98	203·96	2·00029	oxygen.
20	24	75	·00	·00	----	----	399·21	199·59	2·00015	hydrogen.

Comparison of Results.

Experiment 1 is alone in showing impurity in both gases; its result gives 2·00027 for the value sought.

Experiments 2 and 3 showed nitrogen in the hydrogen; their mean is 2·00029.

Experiments from 4 to 12 showed nitrogen in the oxygen; their mean is 2·00021.

Experiments 13 to 17 and experiment 20 showed no measurable impurity in either gas; their mean is 2·00023.

In experiments 18 and 19, carbon dioxide was produced; their mean is 2·00025.

The mean of the seven experiments where oxygen is in excess, is 2·00023, and that of the thirteen in which hydrogen was in excess is also 2·00023. Weights were originally assigned to each result according to the circumstances of each experiment, but they did not change the final mean, and are not given. Four experiments were lost by accident, all others are given. The mean error of a single determination of the ratio is ·000075, or one part in 26000. The final mean value of the ratio is 2·0002.

Summary.

Pure hydrogen cannot be obtained from the purest commercial zinc. By the electrolysis of dilute sulphuric acid, with a proper purifying train, I have obtained hydrogen containing

less than the hundredth of a cubic centimeter of nitrogen in two liters of hydrogen, and containing no other impurity in amount large enough to be detected. By the use of a fusible metal valve, it was possible to obtain any required degree of exhaustion in the part of the apparatus designed to receive hydrogen from the generator. The hydrogen intended to be weighed was not suffered to take up mercurial vapor, nor that intended for analysis to be contaminated with organic matter. A supply of hydrogen sufficient for several experiments was so stored up as to be safe from admixture of air; so that by the apparatus described, the amount of nitrogen in it could be determined in duplicate, and other quantities identical in composition could be used for determining simultaneously the amount of nitrogen in the oxygen used, and also the volumetric composition of water. An apparatus for the measurement of gases has been constructed in which the mean error of measurement of the volume of hydrogen and oxygen used in the experiments has been less than one part in fifty thousand. With this, twenty experiments have been made (four others being lost by accident and not completed), which gave a maximum value for the composition of water 2·00047, a minimum value 2·00005, and a mean value 2·00023. Variations in the process gave no corresponding variation in the result. The mean error of a single determination was one part in twenty-six thousand.

For the present, then, we may believe that water, when the gases are measured under ordinary temperatures and pressures, is composed of 2·0002 volumes of hydrogen to one volume of oxygen; or that under ordinary conditions, the number of molecules in a given volume of oxygen is one nine thousandth part greater than the number of molecules in an equal volume of hydrogen.

Art. XXXII.—*On certain points in the Estimation of Barium as the Sulphate*; by F. W. Mar.

[Contributions from the Kent Chemical Laboratory of Yale College.—VI.]

In the received mode of precipitating barium as barium sulphate, three conditions are carefully observed—absence of excess of acid, slow mixing of the reagents and rest, before filtration, of twelve hours or until the precipitate has completely subsided. Usually, in this process, the precipitate is thrown out in a finely divided, milky condition and settles very slowly. My observation that the precipitate, under certain circumstances, is formed in a more crystalline condition

and settles rapidly led me to investigate the conditions of so rapid a precipitation. These quickly settling precipitates were noticed, in the first instance, in the action of sulphuric acid upon solutions containing a very large amount of potassium chloride with hydrochloric acid in excess. In the course of five or ten minutes the precipitate had completely settled and was found to be in a distinctly crystalline condition and much coarser than the usual form of precipitated barium sulphate.

At the time, it was thought that the cause of this rapid subsidence was the alkaline salt present, and, accordingly, a series of experiments was made in which potassium, sodium and ammonium hydroxides were added in varying amounts to about 400 cm^3 of water, hydrochloric acid added to more than acidity (but not in measured amount), 0·5 grm. of barium chloride introduced, and precipitation brought about by adding dilute sulphuric acid. Sometimes these precipitates settled rapidly, but as often came down in the familiar milky condition. Later, another series of experiments, in which the different conditions were more carefully regulated, was made thus: in 400 cm^3 of water were dissolved 0·5 grm. of barium chloride, 10 cm^3 of strong hydrochloric acid, and amounts of the alkaline chlorides varying from 5 grms. to 0·05 grm., the whole being precipitated with 10 cm^3 of a solution of sulphuric acid made by diluting the concentrated acid with three parts of water. These precipitates all settled rapidly, and the variation in the amounts of alkali seemed to exert no very marked influence. Finally, these experiments seeming to point to hydrochloric acid as the influential factor, a series of experiments was made to test the effect of varying the amount of this acid. From a solution containing in 400 cm^3 0·5 grm. of barium chloride and amounts of hydrochloric acid varying from 1 cm^3 to 50 cm^3, the barium was thrown out by means of 10 cm^3 of dilute sulphuric acid. This series showed that the hydrochloric acid had a very marked effect upon the precipitation of the barium sulphate. When only one or two cubic centimeters of hydrochloric acid were present, the precipitate appeared immediately, in a milky condition, and settled slowly; as the amount of acid was increased, a point was soon reached where the precipitate was not so quickly apparent, but settled out much more quickly and in a coarser condition. With 10 cm^3 to 15 cm^3 of strong hydrochloric acid in the solution, the precipitate settled clear in ten or twelve minutes and was in excellent condition for filtration. When the solution contained 50 cm^3 of the acid, the precipitate settled clear in five minutes. Upon adding the sulphuric acid to such very acid solutions, no precipitate shows for a moment, but then it separates in beautiful crystalline condition and falls almost immedi-

ately. It can be safely filtered with or without pressure in ten minutes. In one instance, in the course of the experiments just detailed, 2 grms. of barium chloride were precipitated in the presence of 30 cm^3 of hydrochloric acid, the precipitate was allowed to settle clear, and was then filtered and washed, the whole operation being completed in seven minutes. This rapid subsidence of the precipitate is seen in hot solutions only —75° C. being the lowest temperature compatible with the attainment of good results, and 85° to 90° better.

To ascertain whether small amounts of barium would be precipitated in like manner from these acid solutions, a series of experiments was made with solutions containing in 400 cm^3, 10 cm^3 of hydrochloric acid and 5, 10, 15, 20, 25, 30 and 50 milligrams of barium chloride, precipitation being brought about as in the experiments above. These solutions remained clear a few minutes and then a very transparent precipitate appeared, but in no case was it as pronounced as the more finely divided precipitate produced in a neutral solution containing 5 milligrams of barium chloride by the same amount of sulphuric acid. However, by giving a circular motion to the solution in the beaker, after about 20 minutes a small conical heap of barium sulphate was collected in each case in the center of the beaker.

Experiments were next undertaken to ascertain whether barium is completely thrown out of solution when precipitated under the conditions related above. The barium salt used in all the experiments described below, was obtained by finely powdering selected crystals of barium chloride and drying by pressure between blotting papers. Portions of the same sample were used throughout. The hydrochloric acid used was the chemically pure article of commerce and had a specific gravity of 1·20. The sulphuric acid used was obtained by diluting the pure concentrated acid with three parts of water and had a specific gravity of 1·28.

In the first series the barium salt was dissolved in about 400 cm^3 of water, 15 cm^3 of hydrochloric were added, and precipitation was brought about by adding 10 cm^3 of the dilute sulphuric acid. The precipitates were filtered, after standing about ten minutes, upon asbestos felts in perforated platinum crucibles.

	$BaCl_2 . 2H_2O$ taken.	$BaSO_4$ found.	Error.
(1)	0·5002 grm.	0·4760 grm.	0·0016 grm.—
(2)	0·5042 "	0·4812 "	0·0006 " —
(3)	0·5038 "	0·4786 "	0·0025 " —
(4)	0·5002 "	0·4760 "	0·0016 " —
(5)	0·5046 "	0·4812 "	0·0006 " —
(6)	0·5038 "	0·4804 "	0·0006 " —

The results of these determinations indicate plainly a loss of barium sulphate, but inasmuch as the felts used had been made very thin and it had been subsequently observed that a small quantity of the sulphate could be collected in one of the filtrates of the series by giving a circular motion to the water, it was thought that the thinness of the felts might offer an explanation of the loss and of the varying results of the series. The following series was, therefore, made in exactly the same manner except that care was taken to have the felts carefully made and reasonably thick.

	$BaCl_2 . 2H_2O$ taken.	$BaSO_4$ found.	Error.
(7)	0·5014 grm.	0·4785 grm.	0·0004 grm. —
(8)	0·2227 "	0·2122 "	0·0005 " —
(9)	0·5003 "	0·4773 "	0·0004 " —
(10)	0·5046 "	0·4814 "	0·0004 " —

These results are uniform and indicate a trifling loss only; though in the filtrates of these experiments, also, a very slight, but, as it proved upon refiltering, unweighable amount of the sulphate could be collected. The precipitate in the last of these experiments was filtered off almost immediately after precipitation, and before it had completely subsided. In another case the whole operation, including the three weighings necessary was conducted to a finish in forty-five minutes.

In spite of the appearance of the trifling deposit in the filtrate, the deficiency in barium sulphate in these determinations was not greater than should be expected from the accepted solubility of that salt in water. To ascertain the effect of strongly acid solutions upon the solubility of barium sulphate the following determinations were made.

In experiment (11) the same amounts of the sulphuric and hydrochloric acids, 10 cm^3 and 15 cm^3 respectively, were used as before, but the total volume was reduced to 100 cm^3. In (12) and (13) the same total volume as before, 400 cm^3, was used, but this volume contained 150 cm^3 of the strong hydrochloric acid instead of 15 cm^3 as in the preceding experiments.

	$BaCl_2 . 2H_2O$ taken.	$BaSO_4$ found.	Error.
(11)	0·5016 grm.	0·4888 grm.	0·0002 grm. —
(12)	0·5004 "	0·4779 "	0·0000 "
(13)	0·5001 "	0·4776 "	0·0000 "

It appears from these experiments that, as in the preceding series, the solubility of barium sulphate in solutions constituted as described is not increased by the free hydrochloric acid, and that the effect upon the solubility when this acid is present in

great strength is to make the precipitate rather more insoluble, if anything, than it is in water. In this connection, it should be remarked that experiments of Fresenius,* together with somewhat similar experience gained by the writer in another line of work not included in this account, point to the fact that the presence of an excess of sulphuric acid is an important condition of this high degree of insolubility. The exact amount of such excess has not been determined, but the amount used in the foregoing experiments seems to be sufficient.

In the preceding experiments, barium chloride was used in considerable quantity. The following determinations were made to ascertain whether very much smaller quantities of barium would come down as completely and as soon, or whether it is necessary to let the precipitations stand longer before filtration. In these experiments the barium salt was measured from a standard solution, containing 200 milligrams of the chloride to the liter. The amounts of hydrochloric and sulphuric acids, 15 cm^3 and 10 cm^3 respectively, and the whole volume of the solution was the same as in the former experiments.

	$BaCl_2 . 2H_2O$ taken.	$BaSO_4$ found.	Time in minutes between precipitation and filtration.	Error.
(14)	0·0030 grm.	0·0024 grm.	120	0·0004 grm. —
(15)	0·0050 "	0·0046 "	150	0·0002 " —
(16)	0·0050 "	0·0023 "	5	0·0025 " —
		0·0043 "	60	0·0005 " —
(17)	0·0050 "	0·0031 "	5	0·0016 " —
(18)	0·0050 "	0·0040 "	10	0·0007 " —
(19)	0·0100 "	0·0078 "	10	0·0017 " —
(20)	0·0100 "	0·0085 "	15	0·0010 " —
(21)	0·0100 "	0·0083 "	30	0·0012 " —
(22)	0·0100 "	0·0087 "	60	0·0007 " —

From these results it would appear that the precipitation, in the presence of hydrochloric acid to the amount indicated, does not take place so rapidly when the amount of the barium salt is small, but that two or three hours are sufficient for reasonably complete separation of the precipitate in any case.

In all the experiments described above there was no attempt at a gradual admixture of the reagents but they were measured out and at once added to the solutions, the whole being well stirred. From the results obtained, it appears to be established, as regards the usual precautions in precipitating barium by means of sulphuric acid, that, contrary to former usage, it is

* Zeitschrift für Anal. Chem., vol. ix, p. 62.

highly advantageous to have the solution strongly acid with hydrochloric acid; that it is not necessary to add the reagents drop by drop, but that the whole quantity required to complete the reaction may be added at once; that ordinary quantities of barium salts, in presence of a considerable excess of sulphuric and hydrochloric acids, are precipitated completely and at once, but that when only a few milligrams are present, the precipitate requires more time to separate under the same conditions. Two or three hours are, however, sufficient, and in no case is the excessive time of twelve hours required.

In the light of the fact demonstrated in the preceding account, that hydrochloric acid may be introduced freely, and without detriment to the quantitative exactness of the precipitation of barium in the form of sulphate from pure solutions, it seemed desirable to look somewhat into the question as to what the influence of a large excess of hydrochloric acid might be upon the well known contaminating effect of alkaline salts present during precipitation, especially as it is customary to attempt the purification of barium sulphate thrown down in the reverse of this process—the determination of sulphuric acid by means of a soluble barium salt—by digestion of the washed precipitate in hydrochloric acid. The following series of experiments was undertaken with this end in view. The details are shown in the tabular statement, precipitation being effected in the presence of free acid and the alkaline salt.

	$BaCl_2 \cdot 2H_2O$ taken.	$BaSO_4$ found.	Error.	HCl in solution.	Alkaline Salts present.	
(23)	0·5092 grm.	0·5032 grm.	0·0169 grm.	+110 cm^3	$KClO_3$	3 grm.
(24)	0·5027 "	0·4907 "	0·0107 "	+ 10 "	"	"
(25)	0·5026 "	0·4944 "	0·0154 "	+100 "	KCl	5 grm.
(26)	0·5045 "	0·4939 "	0·0122 "	+ 10 "	"	"
(27)	0·5020 "	0·4931 "	0·0137 "	+ 10 "	"	"
(28)	0·5013 "	0·4849 "	0·0061 "	+ 10 "	NaCl	"

From the results it is plain that, whatever may be the effect of digesting the washed precipitate in hydrochloric acid, the presence of this acid in large excess during precipitation in the presence of alkaline salts, does not prevent contamination of the precipitate. On the contrary, the greatest contamination seems to have occurred in those cases in which the acid was present to the largest degree, but, in view of the slight variation in contamination as compared with the great differences in the amount of acid employed, it does not appear probable that the increase of acid has very much to do with the amount of contamination.

It likewise seemed to be a matter of some interest in this connection, to investigate the process by which it is currently

supposed* that barium sulphate carrying alkaline salts may be effectually purified, viz: by the solution of the washed precipitate in strong sulphuric acid and reprecipitation by water. Accordingly the determinations of the following series were undertaken. The barium sulphate, precipitated from solutions containing 5 grms of potassium chloride and 10 cm^3 of hydrochloric acid, was collected upon a filter, either paper or asbestos, and, after burning the paper or removing the precipitate from the asbestos (by tapping the crucible which held it and brushing out with a camel's hair brush), was dissolved by warming with concentrated sulphuric acid in a large porcelain crucible and, after cooling, poured into water containing 15 cm^3 to 20 cm^3 of hydrochloric acid. The water into which the solutions in strong acid was poured was warmed with a view to diminish the milkiness of the precipitate, but care must be taken to keep the temperature below 60° C. to avoid danger of spattering on the addition of the sulphuric acid. In the last two of the experiments recorded a large amount of ammonium chloride was added to the water into which the solutions in acid were poured, but this appears to have been without influence upon the purification or the character of the precipitation. The precipitates, after settling clear, were filtered upon asbestos, ignited and weighed, the original felts being employed in those cases in which asbestos was used in the first instance. Those marked with an asterisk were gathered in the first filtration upon paper, the paper being burned in the crucible in which solution of the precipitate was subsequently effected. The remainder were filtered originally upon asbestos.

	$BaCl_2 . 2H_2O$ taken.		$BaSO_4$ found.	Error.	
(29)	0·5026 grm.		0·4746 grm.	0·0044 grm.	—
(30)	0·5035 "	*	0·4830 "	0·0022 "	+
(31)	0·5016 "		0·4767 "	0·0024 "	—
(32)	0·5025 "		0·4804 "	0·0050 "	+
(33)	0·5046 "	*	0·4829 "	0·0010 "	+
(34)	0·5004 "		0·4825 "	0·0047 "	+

These results show, evidently, that this process of purification is not satisfactory. It is possible that the losses observed may have been mechanical, and due to the violent action of the strong acid upon the water, but the excess in weight which is noticed in the majority of the determinations can only be attributed to residual contamination.

Certain experiments, on the other hand, in which the solvent action of sulphuric acid upon barium sulphate is utilized in a different manner resulted more favorably. When a solution of barium sulphate in sulphuric acid is evaporated to dryness, the

* Fres. Quant. Anal., vol. i, p. 547.

salt, as is well known, is deposited in large crystals, which can be filtered off as readily as sand. The following series of experiments show the result of an attempt to utilize this property of comparatively slow and large crystallization in purifying the precipitate Solution of the precipitate was effected as in the experiments described above, and the evaporation of the acid was effected over a matting of asbestos, or by means of a ring burner, in porcelain, which is preferable to platinum when the evaporation is carried on as slowly as is necessary. After the acid was completely evaporated, the crystals were washed upon a felt of asbestos, ignited and weighed. Five grams of potassium chloride and 10 cm^3 of hydrochloric acid were added to the solution of barium chloride in each case.

	$BaCl_2 . 2H_2O$ taken.	$BaSO_4$ found.	Error.	
(35)	0·5029 grm.	0·4796 grm.	0·0006 grm.	—
(36)	0·5008 "	0·4783 "	0·0001 "	+
(37)	0·5038 "	0·4810 "	0·0001 "	—
(38)	0·5087 "	0 4861 "	0·0003 "	+
(39)	0·5025 "	0·4795 "	0·0006 "	+

These results are plainly good and satisfactory so far as concerns the purification of the salt, but, when the evaporation is conducted in the manner described, several hours are needed for the evaporation, and great care must be exercised to obviate the danger of snapping which becomes manifest in the later stage of the evaporation.

By the aid, however, of a Hempel evaporating burner* the operation can be finished safely, and with but little care, in the course of half an hour. The following determinations were made exactly like those of the last series, with the exception that the evaporation was effected by means of the Hempel apparatus.

	$BaCl_2 . 2H_2O$ taken.	$BaSO_4$ found.	Error.	
(40)	0·5050 grm.	0·4824 grm.	0·0002 grm.	+
(41)	0·5069 "	0·4838 "	0·0000 "	
(42)	0·5041 "	0·4825 "	0·0021 "	+
(43)	0·5021 "	0·4812 "	0·0018 "	+
(44)	0·4033 "	0·4801 "	0·0005 "	—

Though not an absolutely perfect process, the purification of barium sulphate by this method of solution and evaporation is evidently better, by far, than the old method of solution and reprecipitation by dilution.

The writer gratefully acknowledges his indebtedness to Prof. F. A. Gooch for many helpful criticisms and suggestions during the course of this investigation.

* Ber. d. deutsch. chem. Ges., xxi, p. 900.

ART. XXXIII.—*On Halotrichite or Feather Alum, from Pitkin County, Colorado;** by E. H. S. BAILEY.

A FEW months since a sample of a mineral was sent by J. J. Crippan, Esq., of Denver, Col., to the Laboratory of the State University for identification. He stated that it came from the Elk mountain range, and was found beside a ledge of "black iron ore." As no record can be found of the description or analysis of this mineral from an American locality, it has been thought that an investigation would be of value. The mineral is quite soft, has a white color, and a beautiful silky luster, resembling that of satin spar. Under the microscope and, to a certain extent, by unaided vision, the mineral appears to consist of capillary crystals arranged in parallel bundles. In some places the crystals, when viewed from the end, are of a green or copperas color. Under the microscope there appear to be attached to some of the fibers minute black particles. In picking the mineral for analysis these specks were eliminated as far as possible. There is only a slight tendency towards oxidation on the surface; and where this occurs the mineral is yellowish red.

The mineral is nearly all readily soluble in water and has a slightly acid, and very astringent taste. It fuses easily in the flame of a candle in its water of crystallization, and as the temperature increases it boils and finally leaves a reddish mass. If, however, the mineral be heated very gradually in a paraffin bath it does not melt or lose its form, but gradually loses its water. Afterwards, if heated nearly to redness, it retains its form, but gradually changes to a red color.

As it was noticed that much of the water was given off at a very low temperature, a quantity of the mineral was heated below 100° C., and, in fact, till just before the close of the experiment, below 85°, and the water thus driven off was collected in a calcium chloride tube and weighed. The mass was thus heated till no more water was given off at this temperature. 33·10 per cent of water was thus eliminated. The remainder of the water was driven off at a much higher temperature; very little, in fact, going off below 250° C.

As the mineral was not completely soluble in water and hydrochloric acid, the solution was evaporated to dryness and silica separated as usual. This silica, or an insoluble silicate, is probably not a proper constituent of the mineral, but so closely associated with it that even in the cleanest and most silky fibers it cannot be separated mechanically. The blowpipe reactions for iron are obtained. If the silky fibers be

* Read before the Kansas Acad. of Science.

dissolved even in cold water, the presence of some ferric salt can be detected by potassium sulphocyanate. The analysis of the mineral for ferric salts was made by dissolving in freshly boiled water in an atmosphere of carbonic acid gas, and afterwards titrating with sodium thiosulphate.

The analysis is as follows:

SiO_2 (and insoluble)	·42
SO_3	33·46
Al_2O_3	12·98
Fe_2O_3	1·60
FeO	5·19
MgO	·17
H_2O (expelled below 100° C.)	33·10
H_2O " above 100° C.)	12·94
	99·86

This is essentially a sulphate of alumina and ferrous oxide, with a part of the former replaced by ferric oxide, and a part of the ferrous oxide replaced by magnesia.

In composition it corresponds quite closely with the Hversalt of Forchhammer, from Iceland. This latter should be probably regarded as a variety of Halotrichite, as the difference in composition is very slight. In the manner of losing its water of crystallization there is an analogy between this mineral and other allied artificial salts; as, for instance, "Green Vitriol," which loses 6 molecules of water at 114° C. but retains the last molecule even at 280°.

Chem. Laboratory, Univ. of Kansas, Dec., 1890.

ART. XXXIV.—*On a new Serpent from Iowa*;* by R. ELLSWORTH CALL.

THE subject matter of this brief notice is based upon four examples of a serpent which have passed into our hands during the past three years, or which have been loaned us for purposes of comparison. Aside from those differences which appear to us worthy of recognition as subspecific in value there is the added interest attaching to the finding of this form so far north and east of the range of the typical species. The typical form ranges, according to Garman,† "from Texas to Kansas;" it is also reported from southern Illinois‡ and from

* Read before the Iowa Academy of Science, January 1st, 1891.

† Samuel Garman, the Reptiles and Batrachians of North America, p. 32.

‡ H. Garman, in Bull. Ills. State Lab'y of Natural History, 1890, p. 188.

Ohio, which reports are the only ones mentioning it as occurring north of the Ohio River. The more eastern forms, as would appear from Mr. Garman's remarks, differ but little from the type that Hallowell had before him in drawing up his description; the chief differences being those of dimension, and the position of the eye with reference to the third and fourth supralabial plates.

To complete the record of the species, the following brief history of the type form is given. The form *lineatum* was described by Hallowell* and referred to his genus *Microps*,† in 1856. Four years later Cope separated it from the genus *Storeria* to which it had been referred by various authors, and made it the type of his new genus *Tropidoclonium*. Certain other forms have been included in the same genus but are now distinguished; with these we have here nothing to do.‡

I propose, therefore, to describe this form under the name of

Tropidoclonium lineatum Iowæ, subsp. nov.

Reptile small; head hardly distinguished from body; eye small, placed over the third and fourth labial plates, circular; head flat posteriorly but before the eyes slightly convex; mouth large, direct to the end of the third labial, thence gently curved to the angle; snout rounded, blunt; head shields nine, frontals quite twice the size of the prefrontals, rostral rather large, somewhat broader than high, blunt or rounded, triangular; nasal one, grooved below the nostril, longer than broad; loreal small, elongate, low, its upper margin on a direct line with the center of the eye and the nostril; preorbital one, excavated, forming a shallow pit in front of eye; postorbitals two, small, subequal, the upper extending a short distance in front of the posterior margin of the eye; one temporal on the left side, two on the right; labials seven, the sixth large, not extending to the edge of lip, but wedged in between the fifth and seventh; the fifth labial the largest; infralabials six, the fourth largest; gulars in three rows; scales in nineteen rows; the small dorsal scales nearly all slightly notched; gastrosteges 143 to 148.

The general ground color above is light chocolate, with a median light—whitish or straw-yellow—stripe extending from the base of occipitals to tip of tail, and occupying all the median scale, and half of the row adjoining on each side;

* Proc. Philad. Academy of Nat. Sci., p. 241, 1856.

† The generic name was bestowed in reference to the very small eyes. This generic name had, however, been preoccupied in the *Reptilia* by Wagler, in 1828, by Agassiz in the Fishes, in 1833; and had also been used in 1823 and 1833 to name genera in the *Coleoptera* and the *Hymenoptera* respectively.

‡ *Vide* Cope in Proc. Philad. Acad. of Nat. Sci., 1860, p. 76; also in Proc. U. S. Nat'l Mus., 1888, p. 391.

there is a much broader lateral stripe, extending from the labials, which are included, to the vent, whence, to tip of tail, the color is uniform chocolate-brown. This lateral stripe is one and one-half scales broad. The base of each of the lowermost dorsal scales is black, which color, however, is subepidermal. The head is inconspicuously mottled with small, irregular, black spots, but the general color is light-brown. The base of each alternate scale, in the fifth dorsal row, is black, causing a peculiar spotted, linear, appearance. The belly is white, with a double row of deep black spots, largest on the middle where, also they are confluent, but entirely wanting on the first two gasterosteges; elsewhere they are present to the end of the tail, but do not at any point reach the edge of the ventral plates.

Of the specimens mentioned in the following table, in which are given all measurements that are thought to be useful, the two first specimens were taken at Ames, Story County, Iowa, the two remaining ones, at Des Moines; both localities are near the very center of the State.

	1.	2.	3.	4.
Gasterosteges	146	148	143	145
Scales, rows	19	19	19	19
Subcaudals, pairs	31	29	18*	35
Length, in inches	14	12·5	8·625*	10·875
Tail, in inches	1·625	1·375	----*	1·375
Tail, times in length	8·61+	9·09	----*	7·89+
Eye, in head	5	5·5	4·5	5·25
Anal plate	entire	entire	entire	entire

From typical *T. lineatum* this variety differs in the number of rows of dorsal scales, in the larger eye, greater size, constant lighter color, in the characters of the markings of the gasterosteges, in the shape, size and grooving of the nasals, and in the number and arrangement of the gulars. In other respects it is closely like the type of Hallowell's form.

Of the specimens which have come under notice, and which have been used in drawing up this description, two may be seen in the museum of the Iowa Agricultural College, at Ames, Iowa; one in the collections of the Indiana University, Bloomington, and one in the West High School, Des Moines, Iowa. As above noted the distribution is thus far restricted to central Iowa.

Des Moines, Iowa, January 5th, 1891.

* This specimen was pathologic, having lost the greater portion of the tail.

ART. XXXV.—*On Crystallized Azurite from Arizona;* by O. C. FARRINGTON.

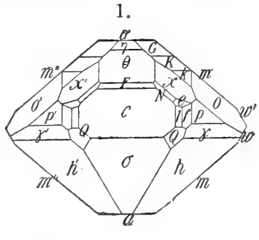
CRYSTALS of azurite from Arizona, remarkable for their number and brilliancy, have for a long time been abundant in collections, but so far as we know no detailed crystallographic study has yet been made of them. The monograph of Schrauf published in 1871,* contains no reference to any specimens from this locality, the only American crystals mentioned being some from Venezuela. Mr. Oliver W. Huntington has described† crystals from Clifton, Arizona, elongated in the direction of the orthodiagonal, a habit which will be referred to later. On these crystals twelve forms were identified, but the crystals, he states, were not suitable for accurate measurement. No further study of the Arizona crystals has been made as far as known.

With a view, therefore, of ascertaining the chief types or habits into which these crystals group themselves as compared with European azurites, and of obtaining as much data as possible toward establishing an exact axial ratio, the writer has made an investigation of them, with material very kindly placed at his disposal by Profs. E. S. Dana and S. L. Penfield. Altogether twenty-one forms were observed on the Arizona crystals, and these are given in the following table, the four marked by an asterisk being new. Previous to this a total number of 54 forms had been observed. The symbols are given in accordance with the position for azurite adopted by Haidinger, Miller and Dana.

c, 001, O	θ, $\bar{1}01$, $1\text{-}\bar{\imath}$	h, 221, -2	o, $\bar{2}41$, $4\text{-}\grave{2}$
a, 100, $i\text{-}\bar{\imath}$	η, $\bar{3}02$, $\frac{3}{2}\text{-}\bar{\imath}$	γ, 121, $-2\text{-}\grave{2}$	*G, $\bar{3}21$, $3\text{-}\frac{3}{2}$
m, 110, I	l, 023, $\frac{2}{3}\text{-}\grave{\imath}$	*N, $\bar{4}47$, $\frac{4}{7}$	*K, $\bar{1}\bar{2}\cdot10\cdot5$, $\frac{12}{5}\text{-}\bar{\frac{6}{5}}$
W, 120, $i\text{-}\grave{2}$	f, 011, $1\text{-}\grave{\imath}$	x, $\bar{1}11$, 1	
σ, 101, $-1\text{-}\bar{\imath}$	p, 021, $2\text{-}\grave{\imath}$	k, $\bar{2}21$, 2	
F, $\bar{2}07$, $\frac{2}{7}\text{-}\bar{\imath}$	*Q, 223, $-\frac{2}{3}$	e, $\bar{2}45$, $\frac{4}{5}\text{-}\grave{2}$	

Fig. 1 shows a basal projection of these forms, from which the principal zonal relations can be determined. The size given to each face indicates its relative importance, and it will be noted that but a small number of forms occur in the negative quadrants.

1.



It was found that all of the crystals examined could be referred to one or the other of four principal habits, which may be designated as the pyramidal, prismatic, dome-like and lath-like habits, the

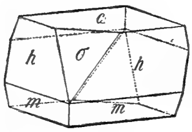
* Sitzungs Berichte, Vienna, Akad., June and July, 1871.

† Proc. Amer. Acad. Arts and Sci., 1885.

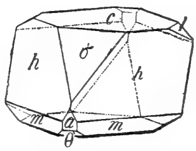
two latter being produced by the predominance of the clinodomes and orthodomes respectively.

Pyramidal Habit.—Figs. 2, 3 and 4. This habit, which is characterized by the predominance of the pyramid *h*, 221, was found to prevail in by far the larger number of the

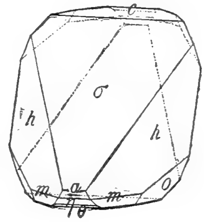
2.



3.



4.



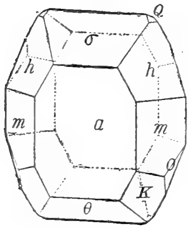
specimens examined. The crystals vary much in size, are usually attached by the basal plane, and the faces *c*, *h*, *m*, and *σ*, are always prominent. Each of these can usually be recognized at a glance, *m* and *h* by the small angle (19° 57′) which they make with one another, *c* by the striations commonly present parallel to the edge *ca* or *cb*; and *σ* from the angle of nearly 45° which it makes with the adjoining faces. Where other faces are present, fig. 3, they are always so small that they could not be confounded with those just mentioned. In the crystal shown in fig. 4, the face *σ* so largely predominates as to give a tabular appearance. A crystal of similar shape from Porto Cabello, Venezuela, is figured by Schrauf (Tafel II, fig. 23) and, as he remarks, from the similarity of the angles *cσ* and *σh*, the crystal at first glance appears to be of a rhombohedral type with *σ* as the basal plane. Aside from the one just mentioned and a crystal from Cornwall figured by Zippe, I have found no other figures of azurite where the pyramid *h* predominates. This habit therefore may be considered peculiar to the Arizona azurites. Though a large number of crystals of this habit were examined, none were found suitable for accurate measurement. The edges are generally sharp and the faces fairly bright, but always so curved or warped as to give a long series of reflections of the signal on the reflecting goniometer.

Prismatic Habit.—Figs. 5, 6 and 7.

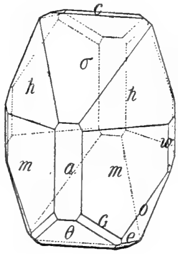
The crystals shown in these figures were all from a Morenci, Arizona, specimen. Some have a comparatively large size, the one shown in fig. 6, being 10^{mm} in length. They were usually attached by the orthopinacoid which varied in the amount of its development, but where large, gave to the crystals an appearance very like the upper portion of the simple cut brilliant, the

orthopinacoid making up the table and the surrounding faces the bezel, fig. 5. Another peculiarity is that all the prominent

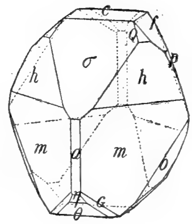
5.



6.



7.



angles are near 45° or 90°. On this crystal, the new form *K*, $\bar{1}\bar{2}\cdot10\cdot5$, $\frac{12}{5}\text{-}\frac{6}{5}$, was observed and its symbol determined from its position in the zone *ah*, and the following measurements.

	Meas.	Calc.
$K \wedge a$, $\bar{1}\bar{2}\cdot10\cdot5 \wedge \bar{1}00$	39° 55′	39° 48′
$K \wedge h$, $\bar{1}\bar{2}\cdot10\cdot5 \wedge 221$	95° 57′	96° 16′
$K \wedge m$, $\bar{1}\bar{2}\cdot10\cdot5 \wedge \bar{1}10$	19° 38′	18° 53′

From the close relation of this symbol to that of the form *G*, $\bar{3}21$, which occurs on other crystals of this habit, it was at first thought that they should be the same, but this face was found to lie outside the zone $m\theta$, and though it was impossible to obtain accurate measurements, all varying from 1° to 2°, the symbol given accords so well with the mean of all, that there can be little doubt of its correctness. The crystal shown in fig. 6 is like the one last mentioned, except in being more elongated in the direction of the vertical axis and in having the orthopinacoid less prominently developed. In fig. 7 the general habit is the same but the crystal is more highly modified. The latter represents a type of common occurrence, the crystals never being completely developed and with the faces often distorted in size and shape, so that they appear as clusters of faces of nearly equal size, without apparent symmetry. They are usually attached along the zone of clinodomes, the basal plane and domes showing striations parallel to the edge *cf*.

In figs. 6 and 7 the new forms *Q*, 223, $-\frac{2}{3}$ and *G*, $\bar{3}21$, $3-\frac{3}{2}$ will be observed.

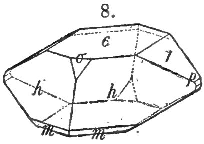
The form *Q* also occurred on the lath-shaped crystals, and as more accurate measurements could be made on these, will be described under that head. The symbol of *G* was determined from its occurrence in the zones *ah* and $m\theta$ and from the following measurements.

		Meas.	Calc.
$G \wedge m$,	$\bar{3}21 \wedge \bar{1}10$,	18° 36′	18° 53′
$G \wedge \theta$,	$\bar{3}21 \wedge \bar{1}01$,	38° 51′	38° 45′
$G \wedge a'$,	$\bar{3}21 \wedge \bar{1}00$,	33° 30′	33° 35′
$G \wedge h$,	$\bar{3}21 \wedge 111$,	102° 17′	102° 29′

Here again, accurate measurements could not be obtained, since, owing to striations and oscillatory combinations, the reflections of the signal were always an unbroken band of from 1° to 4° in length. The measurements given were taken as nearly as possible from the middle of these bands. The form G occurs as a more or less rounded truncation of the edge $m\theta$. It is interesting to note that in the Chessy azurites, according to Schrauf, a like truncation of the edge between the hemi-dome and prism occurs, but in this case in the negative quadrant, that is, the edge $m\sigma$.

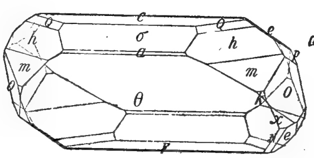
Dome-like habit. Fig. 8.—All the crystals of this habit were found on one specimen, associated with the new mineral spangolite, which is supposed to have come from near Tombstone, Arizona. They are all characterized by being slightly lengthened out in the direction of the clinodiagonal, and by the predominance of the clinodome, l, 023. Striations parallel to the edge cl are common and serve for identifying the faces. A habit similar to this, occurring in the Chessy azurites, is figured by Lévy.*

8.

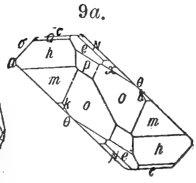


Lath-like habit. Figs. 9 and 10. — Crystals of this habit occur at the Longfellow Mine, Arizona, and all show the same peculiarity of form, due to a lengthening out in the direction

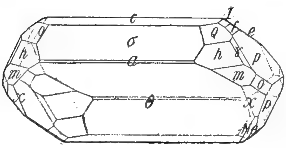
9.



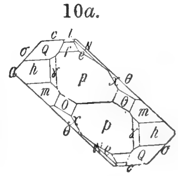
9a.



10.



10a.



of the orthodiagonal and the remarkable development of the orthodome θ. Two crystals were selected as the most nearly

* Atlas, Pl. 64, fig. 25

perfect of these; they were about 5^{mm} in width by 2^{mm} in thickness. In the direction of their length, both were incomplete, the attachment at one end having prevented the development of faces there. Doubly terminated crystals occur, however, where the relative length is about like figs. 9 and 10.

On the crystals selected the new forms Q, 223, $-\frac{2}{3}$ and N, $\bar{4}47$, $\frac{4}{7}$, were observed. The measurements given by the former were very accurate and will be found in the subsequent tables. These, together with its position in the zones *al* and *cm*, sufficiently determine its symbol. Krenner and Franzenau are credited* with having observed this form on crystals from Utah, but no angles are given. The form N has its position in the zone *cm* and $e\theta$, but on account of its blending more or less with the face θ only approximate measurements could be obtained from it in the latter zone. The best obtained were as follows:

		Meas.	Calc.
$N \wedge c$,	$\bar{4}47 \wedge 001$,	38° 33′	38° 34′
$N \wedge x$,	$\bar{4}47 \wedge \bar{1}11$,	16° 20′	16° 17′
$N \wedge \theta$,	$\bar{4}47 \wedge \bar{1}01$,	27° 1′	28° 31′
$N \wedge e$,	$\bar{4}47 \wedge \bar{2}45$,	13° 29′	12° 8′

Figs. 9*a* and 10*a* represent the projection of figs. 9 and 10 upon the plane of the clinopinacoid, by which the zonal relations of the faces are more clearly shown. The close similarity noted by Schrauf of the crystalline form of azurite to that of epidote, amounting, in his view, to a kind of isomorphism, is quite strikingly shown in these crystals, both in their being lengthened out in the direction of the orthodiagonal and in the prominence of the pyramid *o*, $\bar{2}41$, and the clinodome, *p*, 021, each of which correspond in angles to prominent faces in epidote. While I see no reason for regarding the similarity in the crystalline development of the two minerals as anything more than a coincidence, the coincidence is certainly remarkable.

The faces on the free ends of these crystals were nearly all very perfect, and gave sharp, well-defined reflections of the signal, so that the measurements obtained from them possess a high degree of accuracy. The following, taken from the crystal represented in fig. 9, were selected as fundamental, each measurement having been made with great care seven times on the reflecting goniometer, using the high ocular.

$o \wedge o$	$\bar{2}41 \wedge 24\bar{1} =$	65° 5′
$h \wedge h$,	$221 \wedge \bar{2}2\_ =$	105° 39′
$h \wedge o$,	$221 \wedge \bar{2}41 =$	75° 56′

The axial ratio deduced from these is:

$$\grave{a} : \bar{b} : \grave{c} = \cdot 85676 : 1 : \cdot 88603. \quad \beta = 87° \, 36' \, 36'' = 001 \wedge 100.$$

* Zeitschr. Kryst., vol. viii, p. 53?.

In the position adopted by Schrauf the vertical axis is given double the length of that in our position. Taking, therefore, one-half the value which he gives to c, his axial ratio is:

$$\grave{a} : \bar{b} : \grave{c} = \cdot 85012 : 1 : \cdot 88054. \quad \beta = 87° \; 36'$$

It will be seen that these ratios differ but little, the values for β being almost identical, while those for $\grave{a}$ and c agree to the third decimal place. The author's value for $\grave{a}$ is supported by several very accurate measurements of the prism $m \wedge m$, which in every case showed a close approximation to the angle 81° 8′ instead of 80° 42′ as given by Schrauf. Whether this variation is to be regarded as a fundamental difference in the prismatic angle of the crystals from the separate localities or, on the other hand, as so small as to be within the limits of error in observation, I cannot say. More data are needed for deciding the question. The most satisfactory measurements that could be obtained for judging of the correctness of the value assigned to $\grave{c}$, were those of $c \wedge p$, 001 ∧ 021, and $p \wedge p$, 021 ∧ 02$\bar{1}$. The measured and calculated angles compare as follows:

		Calculated.		Measured.	
		Farrington.	Schrauf.	No. 1.	No. 2.
$c \wedge p$,	001 ∧ 021	60° 33′	60° 24′	60° 29′	60° 30′
$p \wedge p$,	021 ∧ 02$\bar{1}$	58° 56′	59° 12′	59° 1′	59° 6′

From these it would seem that the true value of $\grave{c}$ is about a mean between that given by Schrauf and by the author. Here, again, more accurate measurements are needed.

In Table I the measurements of all the prominent zones in these crystals are given and, for comparison, their values as calculated from the author's axial ratio and from that of Schrauf. Where measurements of other crystals were of sufficient accuracy to make them trustworthy, these have been put in the column headed "Other measurements;" but, though a large number were studied in the hope of obtaining such, only a few were found. Tables II and III give the calculated and measured values of the angle of each face upon the pinacoids c, 001, and a, 100. Owing to the imperfect development of these pinacoids in the two best crystals, the measurements given do not have equal significance with those of the preceding table. They are, however, the angles most commonly met with in the Arizona crystals. The clinopinacoid b, 010, was in no case observed. These tables show, as a rule, close agreement of the calculated and measured angular values, and likewise but small differences in the calculated values given by Schrauf and by the author. The chief variations that arise in the latter, correspond to the differences in the prismatic angle which have been previously mentioned. It is to be hoped

that from this or other American localities, more crystals suited for exact measurement may be obtained and thus furnish addi-

TABLE I.

	Calculated.		Measured.		
	Farrington.	Schrauf.	Crystal No. 1. (Fig. 9.)	Crystal No. 2. (Fig. 10.)	Other measurements.
$c \wedge Q$, $001 \wedge 223$	41° 24′	41° 21′	41° 22′	41° 20′	------
$Q \wedge h$, $223 \wedge 221$	26 50	26 51	26 51	26 49	26° 2′
$h \wedge m$, $221 \wedge 110$	19 57	19 58·5	19 57	19 59	19 56
$m \wedge k$, $110 \wedge 22\bar{1}$	20 23	20 24·2	20 23	------	------
$m \wedge x$, $110 \wedge 11\bar{1}$	36 56	36 59·2	37 0	37 4	------
$k \wedge x$, $22\bar{1} \wedge 11\bar{1}$	16 33	16 35	16 37	------	------
$x \wedge N$, $11\bar{1} \wedge 44\bar{7}$	16 20	16 19·5	16 17	16 13	------
$N \wedge c'$, $44\bar{7} \wedge 00\bar{1}$	38 33	38 31	38 34	38 33	------
$a \wedge h$, $100 \wedge 221$	43 56	43 45·5	43 50	43 58	43 50
$h \wedge \gamma$, $221 \wedge 121$	18 11	18 12·5	------	18 15	------
$\gamma \wedge p$, $121 \wedge 021$	26 42	26 51	------	26 37	------
$h \wedge p$, $221 \wedge 021$	44 53	45 4.5	44 52	44 52	44 46
$p \wedge k$, $021 \wedge \bar{2}21$	46 6	46 16	46 3	------	------
$k \wedge a'$, $\bar{2}21 \wedge \bar{1}00$	45 5	44 55	45 19	------	------
$c \wedge e$, $001 \wedge \bar{2}45$	39 50	39 44	39 46	39 46	39 36
$e \wedge o$, $\bar{2}45 \wedge \bar{2}41$	37 36	37 39·5	37 39	37 40	37 33
$o \wedge W$, $\bar{2}41 \wedge \bar{1}20$	13 46	13 49·5	------	------	12 24
$o \wedge \gamma$, $\bar{2}41 \wedge \bar{1}2\bar{1}$	39 32	39 40	------	39 31	------
$\gamma \wedge c'$, $\bar{1}2\bar{1} \wedge 00\bar{1}$	63 2	62 56·5	------	63 3	------
$x \wedge o$, $\bar{1}11 \wedge \bar{2}41$	28 26	28 26·5	29 1	28 32	------
$o \wedge p$, $\bar{2}41 \wedge 02\bar{1}$	51 10	51 25·8	51 11	51 16	------
$p \wedge e$, $02\bar{1} \wedge \bar{2}45$	30 45	30 48	30 46	30 51	------
$c \wedge l$, $001 \wedge 023$	30 33	30 24	30 27	30 31	30 38
$l \wedge f$, $023 \wedge 011$	10 58	10 57	------	10 58	------
$f \wedge p$, $011 \wedge 021$	19 1	19 3	------	19 0	------
$p \wedge p$, $021 \wedge 02\bar{1}$	58 56	59 12	59 1	59 6	------
$p \wedge c'$, $02\bar{1} \wedge 00\bar{1}$	60 32	60 24	60 29	60 30	------
$a \wedge f$, $100 \wedge 011$	88 12	88 12	------	88 16	------
$f \wedge x$, $011 \wedge \bar{1}11$	38 26	38 33	------	38 26	------
$x \wedge a'$, $\bar{1}11 \wedge \bar{1}00$	53 22	53 15	------	53 18	------
$a \wedge Q$, $100 < 223$	57 47	57 42	------	57 50	------
$Q \wedge l$, $223 \wedge 023$	30 9	30 13·8	------	30 6	------
$l \wedge a'$, $023 \wedge \bar{1}00$	92 4	92 4·2	------	92 0	------
$m \wedge o$, $\bar{1}10 \wedge \bar{2}41$	23 50	23 56	23 51	23 50	23 53
$o \wedge p$, $\bar{2}41 \wedge 021$	32 55	32 54	32 48	32 49	------
$m \wedge p$, $\bar{1}10 \wedge 021$	56 45	56 50	56 38	56 39	------

tional data by which to accurately establish the angular values in accordance with which the crystal forms of this interesting and beautiful mineral unite.

In conclusion, the writer desires to acknowledge with thanks, the kindness of those who have furnished him with material

TABLE II.—Angles on basal plane, *c* (001).

		Calculated.		Measured.		Other measurements.
		Farrington.	Schrauf.	Crystal No. 1.	Crystal No. 2.	
m,	110	88° 11′	88° 10·3′	88° 10′	88° 9′	88° 6′
l,	023	30 33	30 24	------	30 31	------
f,	011	41 31	41 21	------	41 28	------
p,	021	60 33	60 24	60 29	60 30	------
Q,	223	41 24	41 21	41 22	41 20	------
h,	221	68 14	68 12	68 10	68 9	68 13
γ,	121	63 2	62 56·5	------	63 3	------
e,	$\bar{2}45$	39 50	39 44	39 46	39 46	------
o.	$\bar{2}41$	77 26	77 23·5	77 24	77 26	------
N,	$\bar{4}47$	38 33	38 31	38 34	38 33	------
x,	$\bar{1}11$	54 53	54 50·5	54 51	54 47	------
k,	$\bar{2}21$	71 26	71 25·5	71 27	------	------
a,	100	87 37	87 36	------	87 38	87 36
σ,	101	44 44	44 46	44 41	44 41	44 42
F,	$\bar{2}07$	16 38	16 40	16 36	------	------
θ,	$\bar{1}01$	47 12	47 15	47 9	47 13	------
η,	$\bar{3}02$	58 53	58 56·5	------	------	58 54

TABLE III.—Angles on the orthopinacoid, *a* (100) and *a′* ($\bar{1}00$).

		Calculated.		Measured.		Other measurements.
		Farrington.	Schrauf.	Crystal No. 1.	Crystal No. 2.	
m,	110	40° 34′	40° 21′	40° 34′	40° 33′	40° 30′
W,	120	59 43	59 41	------	------	60 17
l,	023	87 56	87 55·8	------	87 56	------
f,	011	88 12	88 12	------	88 16	------
p,	021	88 50	88 49	88 52	88 50	------
σ,	101	42 53	42 50	42 46	42 57	42 56
Q,	223	57 47	57 42	57 40	57 50	------
h,	221	43 56	43 45·5	43 50	43 58	------
γ,	121	62 7	61 58	------	62 12	------
x,	$\bar{1}11$	53 22	53 15·5	53 31	53 18	------
k.	$\bar{2}21$	45 5	44 55	45 19	------	------
G,	$\bar{3}21$	33 35	33 26	------	------	33 30
K,	$\overline{12}\cdot 10\cdot 5$	39 48	39 37	------	------	39 55
F,	$\bar{2}07$	75 45	75 44	75 56	------	75 47
θ,	01	45 12	45 9	45 20	45 12	------
η,	$\bar{3}02$	33 30	33 27·5	------	------	33 29

for the work, and the valuable assistance and advice which have been generously rendered him by Prof. S. L. Penfield.

Mineralogical Laboratory of the Sheffield Scientific School, June, 1890.

Art. XXXVI.—*On the Occurrence of Xenotime as an Accessory Element in Rocks;* by Orville A. Derby.

In the examination of the heavy residues obtained by concentration in the *batêa*, or Brazilian miner's pan, of decomposed, or crushed, samples of a large number of Brazilian crystalline rocks, the rare mineral xenotime has been found to be a tolerably constant accessory of one group, viz: the muscovite granites. In comparison with the biotite, amphibole and pyroxene rocks, the muscovite rocks are comparatively rare in Brazil and in the present investigation no opportunity has offered for testing any of a gneissoid type. The samples examined represent an area extending from Ceara on the north to Rio Grande do Sul on the south, the greater portion being from the central part of this area in the States of Rio de Janeiro, São Paulo and Minas Geraes. As regards their geological occurrence the greater number are from small dykes cutting gneiss or metamorphosed (Cambrian ?) schists, a few being from large bosses which, in one case at least, are newer than the schists. These masses are, for the most part, totally decomposed to kaolin, and in some cases have been referred to the muscovite granites from the inspection of the decomposition products alone, so that it is possible that some highly feldspathic rocks of other types, or in which the muscovite is secondary after biotite, have been included. It should be noted that the ones subject to this suspicion are included in the small number that failed to yield xenotime, while in others all the usual accessories were uncommonly rare, and the absence of the mineral may, perhaps, be due to a deficiency in the quantity washed. In these tests about a cubic decimeter was treated and in several instances some of the heavy accessories were so rare that only two or three microscopic grains could be detected in the residue. The usual associates are zircon and monazite, the second rarely, the first never failing to appear in a residue containing xenotime. As the lighter and the iron-bearing accessories, such as tourmaline, garnet, magnetite and titaniferous iron were removed by the use of heavy liquids and the electro-magnet in the preparation of the residues for microscopic examination, no record was kept of their occurrence, though, with the exception of garnet, they were almost constantly found.

The xenotime occurs in the well known octahedral form with the prismatic faces usually barely susceptible. The elongated crystals with highly developed prismatic faces that characterize this mineral in the diamond gravels of various Brazilian local-

ities* have not been observed in any of the washings from material obtained *in situ*. In one case the octahedral edges are modified by faces of the diametric pyramid $1\cdot i$ not cited in any of the descriptions of the mineral that are at hand for consultation. At one locality the characteristic intergrowth with zircon occurs and first led to a suspicion that certain minute octahedral grains apparently too small for any attempt at mineralogical identification might prove to be xenotime, a suspicion that has been fully confirmed by microchemical and optical tests, the last of which were kindly made by Dr. Eugene Hussak.

The crystals rarely attain a length of 1^{mm}, the usual size being about $\frac{1}{4}^{mm}$. In a few localities they are perfectly transparent, yellow or colorless, with highly polished faces. Generally, however, the faces are roughened through alteration, which renders the whole crystal, with the exception of the extreme edges, milk-white and more or less opaque. Owing to their flattened pyramidal form they generally rest in the microscopic preparation in such a position as to readily give the interference cross in convergent polarized light and permit the determination of the positive character of the double refraction and thus prevent confusion with anatase, a frequent companion difficultly distinguishable in some of its forms from xenotime. Samples from 21 different localities have been tested, of which 2 are in Ceara, 7 in Rio de Janeiro, 6 in São Paulo, 5 in Minas Geraes, and 1 in Rio Grande do Sul. In this enumeration a number of small dykes, all affording xenotime, in São Paulo are excluded since they are presumed to be apophyses of a large boss already included. Of these 21 localities 14, or $66\frac{2}{3}$ per cent, gave xenotime always accompanied by zircon and in all but three cases by monazite. Of the 7 which gave no xenotine, 3 afforded such insignificant residues (even the omnipresent zircon failing in one) that a larger amount of material should be tested before a positive conclusion is reached, while two others are probably not true muscovite granites. One of the latter is a small dyke near the Tingua mass of nepheline syenite, from which it is possibly an apophesis and differs from any authentic granite residue yet examined in the character of its zircons, among which geniculated twins occur. The other is a granitic mass in which the muscovite may be secondary after biotite. Eliminating these and one xenotime-bearing rock which appears to be a biotite gneiss, the proportion stands as 15 to 13. That is to say, $86\frac{2}{3}$ per cent of the undoubted muscovite granites that have been sufficiently tested have afforded xenotime, which is thus as constant as any other accessory except zircon. In the biotite gneiss above referred to

* See Gorceix, Sur la xenotime de Minas Geraes (Brésil), C. R., cii, 1886, pp. 1024–1026.

the xenotime occurs with an abundance of monazite in a thin black totally decomposed feldspathic layer intercalated in a black schistose highly micaceous gneiss, which is poor in accessories and, like most of the gneiss and granites in the district (about Petropolis), affords only zircon. This difference and the general character of the layer suggests a suspicion that, instead of a segregation as was presumed without a very close examination, it may prove to be a dyke of muscovite granite modified by dynamo-metamorphism. It is on the xenotime crystals of this layer that diametric faces were observed. Two of the São Paulo localities are of muscovite-biotite granites, one of which forms a considerable boss erupted through Cambrian (?) schists. It is noticeable that these biotite-bearing rocks afford extremely abundant residues of monazite and xenotime, while the zircon is unusually rare. A dyke of lithia-mica granite with muscovite, in the vicinity of one of these bosses, is free from phosphatic minerals, but contains rare grains of cassiterite associated with zircon.

The presence of this yttrium phosphate appears to be in some way dependent on that of potash, since only in the somewhat doubtful case of Petropolis has it been observed outside of the potash-granites, although hundreds of residues have been examined. The same cannot be said of its almost inseparable companion, the cerium phosphate (only three xenotime-bearing residues failed to show monazite, and this, perhaps, owing to deficiency in the quantity of rock washed), which has proved to be very frequent, though less constant, in the biotite gneiss and granites, rare in those containing amphibole. Magmas rich in soda, represented by phonolites, nepheline and augite-syenites, seem to be unfavorable to both minerals, as neither have been found in the dozen or more residues examined. The other companion, zircon, on the contrary, rarely fails to appear in the crystalline rocks, except in the most accentuated basic types—such as diabase, basalts, etc. It may be noted further that in the rocks rich in potash, as indicated by the presence of muscovite, the zircon and monazite in the residues from decomposed material are almost always somewhat altered, being corroded, whitened, and more or less opaque, whereas, in the biotite rocks they rarely show the slightest signs of alteration. The latter observation applies also to the zircons of the soda-bearing rocks as far as these have been examined.

The almost constant occurrence of the cerium and yttrium phosphates, monazite and xenotime, in the Brazilian rocks suggests the hypothesis that they will be found in similar rocks all over the world. A recent visit to the United States has enabled me to test this hypothesis on a small number of North American granites and gneisses. Drift bowlders picked up in

Central New York gave a very characteristic residue of zircon with yellow grains that look exceedingly like monazite, though as I have not as yet been able to subject them to the necessary optical and chemical tests, the identification is not complete. A specimen of granite from Westerly, Rhode Island, kindly furnished by Prof. J. F. Kemp, gives an extremely abundant heavy yellow residue similar in appearance to the Brazilian monazite and, like it, showing the absorption band of didymium when examined under the microscope with the spectroscopic eye-piece.* An experiment with the latter apparatus made for me by Prof. Simon Gage of Cornell University proves that the characteristic absorption bands of didymium and of erbium can be readily perceived on microscopic grains (presumably also in thin rock section, though unfortunately none were at hand for testing) of monazite and xenotime, and thus a very simple and rapid method of detecting minerals containing the cerium and yttrium group of elements is afforded.

ART. XXXVII.—*On the Magnetite Ore Districts of Jacupiranga and Ipanema, São Paulo, Brazil;*† by ORVILLE A. DERBY.

TWO ore districts that have lately been investigated by the São Paulo Geological Survey afford instances of what appears to be a hitherto unnoticed mode of occurrence and association of magnetic iron ores. The districts in question, which agree so closely that they serve to mutually explain each other, are situated about 150 kilometers apart on opposite sides of the Serra do Mar. That of Jacupiranga is in a region of comparatively low hills at the extremity of a high ridge of the Serra do Mar system, rising from the low plains of the coast and of the lower course of the Ribeira (or Iguape) river. The Ipanema ore deposits are in the center of an isolated mountain block, bounded by fault planes that rise some 300 meters above a plain that is essentially horizontal with a mean elevation of about 700^{m}. The basement rocks in both districts are

* An examination, not yet concluded, kindly made by Dr. G. H. Williams, seems to prove that this cannot be monazite. Whatever it may prove to be, it illustrates the value of the batea in petrographical study, as by its use an abundance of a rare and interesting accessory was obtained with about ten minutes' work.

† This paper is an English abstract of two reports prepared in the Portuguese language for publication in the Boletina da Commissão Geographica e Geologica de São Paulo, by the present writer, with the coöperation, in the case of the Ipanema district of Dr. Luiz Gonzaga de Campos. The petrographical work has been carefully revised by Dr. Eugen Hussak while Mr. Henry E. Bauer, an able amateur geologist and volunteer assistant, has furnished much valuable material and information regarding the Jacupiranga district.

the same and identical with the characteristic formation of the intervening position of the Serra do Mar, which in this region is made up principally of a series of more or less completely metamorphosed schists cut by numerous and extensive eruptions of granite. These schists are mainly clay-slates, but more highly metamorphosed argillaceous strata appear and more rarely quartzites. One or more beds of limestone, generally black and amorphous but frequently altered to marble, form a very characteristic and presistent member of the series. As no fossils have yet appeared the age of this series cannot be made out, but it is certainly pre-Devonian and presumably Cambrian. The plain surrounding the Ipanema mass, as well as a portion of the block itself, is of late Carboniferous or Permian age. The eruptive rocks described below while in the main confined to the Cambrian (?) area have been found at a few points cutting the Carboniferous strata. At Jacupiranga on the contrary nothing with the exception of eruptive rocks has been recognized between the ancient formation and the modern alluvial deposits, so that there is no criterion for determining the age of the eruptions.

For purposes of study the Jacupiranga district far excels that of Ipanema not only in the variety of its rocks, but also in their state of preservation.* The one district proper includes an area of 30–40 square kilometers of nearly rectangular form lying to the west of the small river Jacupiranga, and extending well over towards the great parallel stream, the Ribeira, which below its great bend, receives the Jacupiranga. The divide between the two streams consists of gneiss and granite flanked on each side by Cambrian (?) schists cut by a great variety of eruptive rocks. These last include various types of orthoclase-pyroxene, orthoclase-nepheline, and plagioclase-nepheline rocks, nephelinites, teschinites, vosgesites, basalts, etc. In the study of the field relations of these various groups, made in great part by Mr. Bauer, in part by the writer with the assistance of Drs. Campos and Hussak, an intimate connection between the most of them and with the iron ore, has been directly proven in many cases and is strongly suspected in others.

The ore district proper is for the most part heavily wooded and covered with a rich dark soil containing everywhere a greater or less amount of magnetite in grains or blocks ranging in size from the finest sand up to masses of the size of a man's head. The predominant rock, as seen in the deeper parts of the cuttings, is a dark-brown or black schist in inclined layers with an abundance of mica flakes along the division

* Unusual facilities for examination were afforded by the operations (since suspended), for the erection of iron works. These included several large excavations for foundations and the grading of six kilometers of tramway affording a nearly continuous section across a large portion of the district.

planes, which give it the aspect of a mica schist. Sections from the inner portion of one of these mica-covered slabs (the outer micaceous portion is too friable for section cutting), show the rock to be composed almost exclusively of irregular grains of violet-colored titaniferous pyroxene with, as accessories, an abundance of iron minerals (magnetite and titaniferous iron), rare grains of perofskite and milky white grains, in part apatite, in part a zeolitized silicate. No mica can be seen in these sections. Higher up in the cuttings where the rock is so friable as to readily crumble in the fingers, the mica becomes more abundant, lining not only the original planes of schistosity but all secondary divisional planes including those between the partially disaggregated grains of pyroxene. The origin of the mica from the weathering of the pyroxene is perfectly clear, and higher up in the cuttings the rock is seen to lose entirely its lithoid character, and to pass to a yellow clay composed exclusively of decomposed mica flakes.* This in turn passes to a dark-red soil which, like the yellow micaceous clay affords, on washing, the characteristic residue of the sound pyroxene rock, viz: iron minerals, apatite and perofskite.

At many points throughout the district, the iron minerals in the rock above described rise from the rôle of an accessory to that of an essential element giving layers composed of various proportions of pyroxene and magnetite which, by the disappearance of the pyroxene, pass to a pure iron ore. This enrichment in iron is accompanied by the total disappearance of the white silicate, and a diminution in the quantity of perofskite. In specimens of nearly pure ore, the magnetite forms a continuous network enclosing detached grains of pyroxene in the same manner as the metallic portion of a meteorite of the mesosiderite type encloses the silicate portions. The annexed figure from a microphotograph of a section of Jacupiranga ore represents this structure. In one place a layer about 15 centimeters thick of pure magnetite containing pyroxene (in part altered to mica) only in a thickness of a few millimeters at the upper and lower surfaces, was seen *in*

* This wholesale passage of pyroxene to mica through weathering is a capital feature in the geology of the two districts and has been very carefully verified. It is not confined to any particular kind of pyroxene as it has been noted also in acmite-bearing rocks and in the pyroxene rocks associated with marble beds.

situ intercalated in schist in which the pyroxene predominates over the magnetite.

At other points flaggy layers were found in which a white element is equally abundant with the pyroxene. This in well preserved specimens proves to be nepheline and the rock standing alone might be called a schistose nephelinite. In this type the iron minerals are rare, while perofskite, apatite, and primary biotite are constant, olivine a frequent accessory.

The peculiar rock above described might very properly be called a pyroxenite if it were not for the objection that this would add still another to the very heterogeneous (as regards geological relations) reunion of types to which that name has been applied.* In view of the evident necessity of subdividing according to geological origin, the so-called pyroxenites, it seems necessary to distinguish this by a distinct name, and it will here be called *jacupirangite*. The rocks included under this title are allied to the nepheline-bearing series and present the various types of pure magnetite, magnetite with accessory pyroxene, pyroxene with accessory magnetite, and pyroxene and nepheline with biotite and olivine as accessory or (in the case of the former at least) essential elements. All these types are most intimately associated as parts of the same mass and the gradual passage from one to the other has been most satisfactorily proven. The most constant and characteristic element is a violet titaniferous pyroxene. Another type of pyroxene-nepheline rock (nephelinite) characterized by green pyroxene and abundant biotite occurs in the district, but has only been seen rarely in loose masses and is presumed to come from dykes and to have an intimate relation to the jacupirangite. At Ipanema a rock of similar mineralogical composition cuts the Carboniferous strata.

The relations of the jacupirangite to the other rocks of the district are not clear. The nepheline-bearing varieties are suggestive of an eruptive origin and the phenomena observed about a long narrow ridge of limestone of presumed Cambrian age, that rises near the center of the jacupirangite area, appear to confirm this suggestion, although no actual contact could be observed. The limestone is a white, coarsely crystalline marble, heavily charged in places with crystals of magnetite and

The mica shows the optical properties of biotite but chemically (at least in the decomposed state in which it could be obtained for analysis), it is essentially a hydrated silicate of iron and alumina.

* In Brazil alone three or four distinct groups of pyroxenite have been recognized. Aside from the one here described, there is one associated with the limestone of the Cambrian (?) series and undoubtedly derived from it through metamorphism. Another is similarly associated with limestones of the gneiss series and still another forms dykes in gneiss. The calcareous groups are rich in scapolite and apparently correspond with a part of the pyroxenites of Barrois and Lacroix, but none agree with the original type as established by Dana for rocks on the Hudson, whose genetic relations seem to be with the peridotites or norites.

apatite. In an opening close to the supposed contact the jacupirangite (profoundly decomposed) is of much coarser texture than is ordinarily the case, with large perfect crystals and crystalline groups of magnetite, an unusual amount of apatite, and large flakes of hydrated biotite with perfect crystalline outlines that appear to form a primary constituent of the rock. The limestone in the neighborhood of the contact contains orthite, which is found abundantly in beautiful microscopic crystals in the sands of the streams flowing from the limestone ridge, but has not been met with elsewhere. At the margin of the area a small isolated hill of Cambrian (?) schists and eruptive rocks of a different type is partially surrounded by jacupirangite, but the contact zone is occupied by swamps. In the saw-mill pit small dykes of foyaite (nepheline-syenite) are seen cutting the jacupirangite which, near the contact, shows large mica flakes as at the supposed limestone contact.

At Ipanema an ore pit in what is presumed to be decomposed jacupirangite shows clearly the eruptive origin of the iron-bearing rock at this place, since it presents a well characterized dyke margin against decomposed schist and, for a distance of a few meters from this margin, a well defined breccia

character due to the inclusion of irregular angular fragments of the schist, as shown in the annexed reproduction of a photograph, in which the lighter colored schist fragments are seen scattered helter-skelter in the dark iron-bearing rock. The

latter is, for the most part, a granular mixture of small irregular grains (often perfect crystals in the leaner ores) of magnetite and decomposed mica, that passes abruptly to a micaceous clay almost free from iron. In this, as in general appearance, abundant residue of apatite and other particulars, it agrees with the decomposed rock of Jacupiranga, the only noticeable differences being in the less apparent schistosity and absence of perofskite.* Unfortunately no sound rock of this type could be found at Ipanema, but in view of the similarity in the decomposition products, the close correspondence in the eruptive rocks of other types in the two districts and the lack of any primary mica-magnetite type to which the Ipanema rock can be referred, it seems quite safe to consider the latter as decomposed jacupirangite and to conclude for the eruptive origin at both localities.

The above described mode of occurrence is the only one that has been observed in the Jacupiranga district. At Ipanema on the contrary only a small portion of the ore in sight can be referred to the Jacupirangite type of rock. The greater part occurs as a superficial drift-like deposit resting (where the underlying rock has been seen, in the extension of about 100 meters) on micaceous clay which according to all the indications results from the decomposition *in situ* jacupirangite free from iron. The ore masses are rounded as if water-worn and vary in size from shot-like grains to blocks of half a cubic meter or more. These for the most part differ in aspect from the jacupirangite ores and, when impure, contain, instead of decomposed mica, nests of granular apatite and masses of secondary silica (chalcedony, quartz and rarely tridymite). Large rounded bowlders of secondary silica with or without inclusions of ore are abundant. In these the only recognizable minerals, aside from the magnetite, are decomposed mica, rare prisms of green pyroxene (acmite) and exceedingly fresh enstatite in large grains much invaded by chalcedony. It is evident from the inspection of the blocks of this superficial deposit that, with the exception of a small part that can be referred satisfactorily to the jacupirangite type, the magnetite occurs as segregations in a rock extremely subject to alteration with separation of secondary silica. This rock contained magnetite, apatite and acmite as primary constituents without original free silica. Whether the mica and enstatite are primary constituents or not could not be determined, but it is strongly suspected that they are not. In this case it may be surmised that they point to original pyroxene and a magnesium silicate probably olivine.

* This is in accord with the general character of the ores, that of Ipanema being a pure magnetite, while that of jacupiranga is highly titaniferous.

An abandoned working badly obscured by forest shows the ore masses *in situ* as rounded aggregates in soft decomposed material which higher up the hill in the natural exposures is charged with secondary silica giving the siliceous masses above described. The whole evidently forms a dyke some ten meters or more in width cutting the Cambrian (?) schists. In the soft material only decomposed mica (perhaps original biotite) could be recognized. A washing gave an extraordinary abundance of apatite and rare prisms of acmite. A loose block with schistose structure consisting of a finely granular mixture of apatite and acmite (the latter showing micaceous decomposition) serves to connect this cutting with another in the vicinity.

A small dyke about 20 centimeters wide and about 100 meters distant from the one above described has afforded specimens in which the original rock-type can be recognized. It consists almost exclusively of orthoclase with some large crystals porphyritically developed in a fine grained holocrystalline ground-mass with rare prisms of acmite and is thus a typical augite-syenite.* Lower down the hill and apparently coming from the same or a similar dyke are some large partially decomposed, partially reconstructed (with secondary silica) blocks of extreme interest. The soft material and the totally reconstructed (with quartz, chalcedony and tridymite) portions closely resemble those of the old mine above described and the latter also contain enstatite. In other portions in which the orthoclase is partially preserved in a kaolinized state the introduction of secondary quartz gives the aspect of an ordinary granite. The acmite is in great part transformed to amphibole and finally to mica. It varies greatly in abundance becoming in places the predominant element and with its increase, apatite substitutes in great part, or wholly, the feldspathic element giving a rock composed entirely of pyroxene and apatite. There is thus at this place an intimate association of three apparently distinct types, viz: an orthoclase-pyroxene rock with predominant feldspar, an orthoclase-apatite-pyroxene and an apatite-pyroxene rock. These last two give on decomposition an apatite-mica rock.

A large road cutting on the opposite side of the ravine and nearly in front of the locality last described is in totally decomposed schistose material in highly inclined layers. The predominant rock is a pyroxene-apatite schist in which the pyroxene (acmite) has, except in a few points, been wholly altered to mica. Through this run narrow dyke-like streaks (particularizations ?) relatively poor in apatite in which the

* The daily increasing importance, wide range of variation and peculiar character of the orthoclase-pyroxene combination seems to demand a simple non-committal term as a generic title for so-called augite-syenite group and Brögger's name *Laurvikite* is here employed in that sense.

white element appears to have been feldspar. This resembles the decomposed schist fragments contained in the ore breccia and like them is characterized by an abundance of zircons of peculiar type. In the midst of these schists appear irregular bands and patches (dykes?) of purely micaceous material exactly resembling the iron-free portions of the eruptive rock of the breccia and like it enclosing fragments of schist. The mica-apatite schists also contain several streaks of a much whiter more compact material that look exceedingly like dykes but may perhaps be particularizations. In these mica and apatite are the only recognizable constituents, but it is tolerably certain that a large part of their mass was originally feldspar. One of these streaks about 5^{cm} wide has a central line of rounded aggregates, the size of a walnut, of magnetite and apatite exactly resembling, on a small scale, the bowlders of the superficial ore deposit and the aggregates of the large dyke (p. 12). Large blocks of magnetite scattered about the neighborhood of the cutting indicate that larger aggregates occur though none were seen *in situ.* This little dyke or streak shows that considerable aggregates of magnetite do actually occur in a rock which is presumably a phase of laurvikite and thus permit the reference to that type of the large decomposed dyke with its workable ore bodies.

The decomposed schist of the ore breccia gives on washing an abundant slime of mica flakes and kaolin with a residue of microscopic zircons* of peculiar type and rare grains of undecomposed orthoclase and aconite thus indicating an original orthoclase-pyroxene rock. Just such a rock, characterized by the same peculiar type of zircons, is found in a sound state in the schist hill (Morro de Area Preta)† at Jacupiranga mentioned on p. 800. It here cuts across and is insinuated between the layers of an ordinary metamorphosed Cambrian (?) schist containing quartz, mica, tourmaline and staurolite, in such a manner as to form an extremely curious complex of regular alternating layers, often only a few millimeters thick, of eruptive and rudimentary material. This schistose phase of laurvikite occurs again in a low ridge at a place called Modesto a kilometer or so above the Morro de Area Preta, but here it is itself included in a breccia of which the matrix is the pyroxene-apatite (with subordinate orthoclase) phase of the same rock similar to that already described from Ipanema.

Indications of the genetic relations and geological age of this last phase are afforded by a cutting on the tramway at Ipanema

* These are complicated crystals of the Miask type in strong contrast with the simple prismatic forms found in many scores of washings from the ordinary feldspathic rocks such as gneiss, mica schist, granite, syenite, foyaite, phonolite, diorite, etc.

† Black Sand Hill from the abundance of magnetite in the stream at its base.

where a decomposed intrusive sheet of a highly micaceous rock is intercalated in the Carboniferous sandstone and shale. This includes lenticular nodules that have escaped decomposition varying in size from that of an egg to that of a bushel measure. These consist of the orthoclase-pyroxene (with subordinate apatite) and pyroxene-apatite (with subordinate orthoclase) combinations identical in aspect, both macro- and microscopically, with the rocks from the ore locality at the same place and from the Modesto locality at Jacupiranga. At this place, owing to the decomposition of the enclosing rock, no idea can be found of the origin of the nodules which appear like transported blocks. At another point where the rock is better preserved small aggregates of the same nature seen in microscopic slides are evident segregations. The enclosing rock has a porphyritic structure with large phenocrysts of nepheline, apatite, green pyroxene (acmite) and biotite (extremely abundant) in a fine grained ground-mass too much altered for determination. It had thus the structure and aspect of a phonolite although no feldspar could be detected in it* and the biotite is much more abundant than is usual in the ordinary phonolites. In composition it recalls a coarse holocrystalline nephelinite found in loose blocks at Jacupiranga. A comparison is also suggested with some of the rocks from the Azores and Masai Land called acmite-trachyte by Mügge. A rock of this last type with phenocrysts of sanidine brown pyroxene and haüyne in a felt like ground-mass of orthoclase, acmite and possibly nepheline (since the former gelatinizes freely) occurs in considerable masses at Jacupiranga somewhat to the westward of the ore district.

The above observations indicate in the phases of laurvikite here described a genetic relation with nepheline-bearing rocks and a tendency to a schistose structure, and to abrupt changes in mineral composition, especially in the direction of phosphatic and basic segregations, that is found to a greater or less extent in other phases of the same type at various localities in Brazil. Thus, at two points in the Jacupiranga district and at Cabo Frio, a coarse granitoid laurvikite with rare grains of nepheline and abundant biotite is associated with foyaite masses. A fine grained phase of the same type found in considerable bodies in various outlying hills about the Jacupiranga ore district and in a few loose blocks within it, show a tendency to a linear arrangement of the bisilicate elements (pyroxene, hornblende and biotite) that gives a gneissoid aspect to the rock. The same tendency is seen in an angular fragment

* This may be due to decomposition though as the nepheline is still recognizable it seems singular that orthoclase should have been less persistent. In the segregations nepheline is totally excluded and primary biotite is rare.

enclosed in the foyaite of Tingua (the only specimen of laurvikite found at this locality) in which pyroxene and magnetite are linearly arranged.* A small loose block found associated with foyaite at Jacupiranga has large idiomorphic phenocrysts of dark violet pyroxene, full of inclusions and with beautiful zonal structure, embedded in a holocrystalline ground-mass of orthoclase with abundant bisilicates (green pyroxene and biotite) and occasional grains of plagioclase. This rock, which illustrates beautifully the tendency towards a basic type, presents some features that suggest a comparison with certain phases of jacupirangite. The frequent occurrence of olivine as an accessory in rocks of the laurvikite type also points in the same direction and suggests a possible hypothesis to account for the presence of enstatite in some of the Ipanema rocks.†

In this connection it is interesting to note the same tendency to a basic phase in the granitoid, or foyaite, type of nepheline-bearing rocks. At several points in the Jacupiranga district, considerable masses (dykes ?) appear of a plagioclase-pyroxene-biotite rock that has been referred to diabase or gabbro by several eminent petrographers to whom they have been submitted. At two points the blocks of this type are mingled with those of foyaite in a manner to suggest a geological connection, while occasionally, as at Cabo Frio, also particularizations of the same type have been observed in the latter rock. Moreover, a diligent search made by Dr. Hussak reveals an occasional grain of nepheline in the plagioclase rock. A rock of similar character with idiomorphic violet pyroxene and an abundance of olivine also contains rare nepheline grains and is referred to the same type‡ as is also a plagioclase-analeime-pyroxene rock identical in all essential particulars with the teschenite of Elgoth, Silesia, that occurs near the river Ribeira at Jaguary. These plagioclase rocks, which may be compared with the theralithes of Montana and the teschenites of various localities, simulate closely the diabases and gabbros, but differ in their genetic relations, from the ordinary types of that family. Various other peculiar types of eruptive rocks abound in the Jacupiranga district, but so far as known they have no

* The quantity of magnetite in this rock would be large for a rock of purely basic type and is extraordinary for one in which orthoclase is the predominant element. It shows the tendency to basic segregations that culminates in the Ipanema on bodies.

† If the enstatite is primary it is extraordinary that a mineral so subject to alteration should be perfectly fresh while all the other elements, except magnetite and apatite, are altered beyond recognition. If secondary it might have been formed from original olivine as suggested above, or possibly from the magnesia of the decomposed pyroxene.

‡ This, with more abundant nepheline, would correspond very closely with the theralithe of Crazy Mts., Montana.

bearing on the magnetic question. For the most part they are of a basaltic character* corresponding to the rocks referred to augitite, limburgite and tephrite (?) that abound in small dykes in every Brazilian locality of foyaite with which they appear to have some genetic connection. One contains leucite, the third occurrence of that mineral noted in Brazil. Small basic dykes, totally decomposed, but apparently of the same character, cut the Carboniferous strata at Ipanema.

Specimens of magnetite ore from various other points in Brazil in the states of São Paulo, Minas Geraes, Sergipe, Parahyba, etc., show inclusions of decomposed mica and apatite that suggest a comparison with the Ipanema and Jacupiranga ores, and perhaps indicate that the mode of occurrence above described may be quite general. In view of the tendency to a schistose structure and transformation into siliceous masses, it may be suggested that possibly some of the jaspery hematites may have had a similar origin.† The only Brazilian magnetite thus far seen that can be definitely determined as having a different origin is from Palmeiras dos Indios in the state of Alagoas. This, which is similar in appearance to the Cumberlandite of Wadsworth, contains plagioclase and augite and is an enrichment of a gabbro.

ART. XXXVIII.—*On Pink Grossularite from Mexico;* by C. F. DE LANDERO.

THE occurrence of pink colored garnets at Xalostoc, District of Cuautla, State of Morelos, Mexico, has been known for some years and specimens from there have been preserved in the mineralogical collections of the School of Mines, in the city of Mexico; but the locality had not been properly explored, the specimens obtained being merely from the surface. About the beginning of the year 1890, Prof. Urquiza gave me, in the city of Mexico, some of these specimens, better than those I had formerly seen: in August of the same year I gave a few of them to Mr. William Niven, of New York City, the diligent mineralogical explorer. Mr. Niven was so much pleased

* The exception is the Vergesite described by Rosenbusch (Mik. Phys. Gesteine, 2d ed., p. 820) from material sent by Mr. Bauer from the Serra do Hilario on the divide between the Jacupiranga and Ribeira. This has been traced in a large dyke for over six kilometers.

† While there is no evidence of any dynamo metaphoric action at Ipanema affecting the larger blocks of magnetite, they have suffered the martite alteration to such an extent that several European mineralogists who have examined the ore prefer to call it martite or hematite.

Since the above article was written a dark green spinel (hercynite?) has been found to be an abundant accessory in the Ipanema magnetite.

with the rose-colored crystals, that he proposed to visit the locality; this he accomplished in the early part of January of this year, and succeeded in obtaining excellent specimens of both pink and colorless grossularite. On his return from his trip, he gave me a number of crystals, and since the material was very pure and well suited for chemical work, I decided to analyze it. This I have done in my laboratory, with the assistance of my colleague Prof. R. Prieto.

We selected for the analysis, small, clean, almost transparent fragments of rose-colored crystals. The specific gravity was found, by pycnometer to be 3·516 at 19·8° C. The qualitative analysis proved the presence of silica, alumina, lime, magnesia, and traces of ferric oxide and manganese. Manganese, though probably the coloring matter, is present in so minute quantity, that its reaction with the borax glass could not be obtained, not even by using a fragment of saltpeter to oxydize the glass. Its presence was however ascertained by fusing the powdered mineral with sodium carbonate, a greenish mass being obtained; this was dissolved in water, with the addition of pure nitric acid, and the clear liquid poured over lead peroxide; after a little time the liquor became pale amethyst-colored.

For quantitative analysis 0·870 grams of very pure carefully powdered material were fused with 3 grams of the usual mixture of dry carbonates of potash and soda, in a platinum crucible, over the flame of a gasolene vapor laboratory lamp (Dangler's): the mass obtained was dissolved slowly, in very dilute hydrochloric acid, and the silica, alumina, iron, lime and magnesia were determined in the usual manner. The amount of the original mineral that was not attacked by the alkaline carbonates was ascertained by treatment of the weighed silica, with ammonic fluoride, weighing the residue left, and approximate calculation of the corresponding weight of the mineral.

The results obtained were the following:

		Per cent.	Atomic Ratio.	
SiO_2	0·3535	40·64	58·92=3·10	
Al_2O_3	0·1868	21·48	18·13	1·
Fe_2O_3	0·0137	1·57	0·86	
CaO	0·3078	35·38	54·98	2·98
MgO	0·0065	0·75	1·62	
MnO,BaO	trace	trace		
Unattacked mineral	0·0015	0·17		
	0·8698	99·99		

The atomic ratio for SiO_2, R_2O_3 and RO is very nearly 3 : 1 : 3, the normal ratio for the minerals belonging to the garnet group. The formula for the analyzed grossularite, may be written: $[Ca, Mg]_3\ [Al_2, Fe_2]\ Si_3O_{12}$.

All the Xalostoc crystals I have seen are rhombic dodecahedrons (i); many of them have a tolerably distinct dodecahedral cleavage. Their hardness is 7·5, and their fusibility a little below 3. By fusion before the blowpipe a yellow glass is obtained; before Fletcher's hot blast blowpipe, fusion is accompanied by intense glowing and a white blebby glass is obtained.

Guadalajara, Mexico, February 18th, 1891.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *On the Determination of Vapor-Pressures.*—A new method for determining the vapor-pressures of solutions has been described by Charpy. The solution to be examined is contained in a large test tube, in the upper portion of which a small condensation hygrometer is placed. After allowing the space above the liquid to become saturated with the vapor of the solvent, accelerating the process by reducing the pressure if necessary, the dew point is determined. Knowing the law according to which the vapor-pressure of the solvent varies, the vapor-pressure of the solution at the temperature of the experiment can be readily calculated. The accuracy of the determination is the greater, the less the pressure that is to be measured. One advantage of this method is the fact that it may be applied to solutions which attack mercury and cannot in consequence be introduced into a barometric tube.—*C. R.*, cxi, 102; *J. Chem. Soc.*, lviii, 1364, Dec. 1890. G. F. B.

2. *Vapor-densities at low Temperatures.*—The method of Demuth and Meyer for determining vapor densities below the boiling point,* has been found by Krause and Meyer to be still applicable when in place of hydrogen, other gases such as air, nitrogen or even carbon dioxide, are used to fill the vaporizing bulb. Although the vaporization is then much slower, perfectly accurate results are obtained; as the authors have shown by their determinations of the vapor-density of xylene at 40° below its boiling point and of paranitrotoluene at 33° below, in air and in carbon dioxide. It is preferable to use hydrogen however in all cases where it is practicable. Experiments made by the authors show that the theoretical vapor-density of acetic acid is reached at about 160°; the values obtained steadily diminishing from 2·60—2·67 at 100°, to 2·12—2·18 at 160° and 2·07—2·14 at 190°; the theoretical vapor-density being 2·08. Cahours, using the method of Dumas, reached the theoretical vapor density of acetic acid, only at 250°. Iodine allowed to vaporize at the tempera-

* See this Journal, III, xxxix, 312, April, 1890.

ture of boiling sulphur in presence of a large excess of air, showed no sign of dissociation; although according to Troost, it is dissociated when thus treated under a diminished pressure. An experiment with sulphur itself at this temperature, in an atmosphere of nitrogen, gave a vapor-density corresponding to the formula S_7; but this result is apparently accidental.—*Zeitschr. physikal. Chem.*, vi, 5; *J. Chem. Soc.*, lviii, 1365, Dec. 1890.

G. F. B.

3. *On the Dispersion of Carbon Compounds.*—Measurements of the refractive and dispersive powers of the simple and mixed ethers of the methane series by BARBIER and ROUX show that the dispersive power and the specific dispersive power increase with the molecular mass, but remain practically the same for all isomerides containing the same quantity of carbon. The introduction of CH_2 into the molecule raises the specific molecular dispersive power by about 8·2. In methyl-, ethyl- and propyl-allyl ethers the dispersive power and specific dispersive power remain practically constant and do not increase with the molecular mass. If these ethers are compared with others containing the same number of carbon atoms, it is seen that the dispersive power increases as the proportion of hydrogen decreases. With methyl-, ethyl-, propyl-, isobutyl- and amyl-benzyl ethers, the dispersive power diminishes as the molecular mass increases, but the addition of CH_2 produces a variation in the specific molecular dispersion equal to about 8·2, as in the methane series. In all cases the specific molecular dispersive power of the ethers is equal to the sum of the dispersive powers of the two alcohols from which they are derived, less the dispersive power of the water eliminated.—*C. R.*, cxi, 180; *J. Chem. Soc.*, lviii, 1353, Dec. 1890. G. F. B.

4. *On the Electrical Properties of Semi-permeable Walls.*—A semi-permeable material, according to OSTWALD, is a material which permits the solvent to pass through it but not the dissolved salt. The permeability of a given material, however, depends not on the nature of the given salt as a whole, but upon the character of each of its ions. Copper ferrocyanide for example is permeable by potassium chloride, because it allows both the potassium and the chlorine ions to pass through it. But it is not permeable by barium chloride because it does not permit the barium to pass, nor by potassium sulphate because it does not allow the passage of the SO_4 ions. If a solution the ions of which cannot pass through a semi-permeable material be electrolyzed, the electrodes being separated by a semi-permeable wall, the latter will itself act as a metallic electrode. In the author's experiments, a U-tube filled with a solution of potassium ferrocyanide and having parchment paper tied over its ends, was used to connect two glasses containing solution of copper sulphate; so that a layer of copper ferrocyanide formed on the paper. After passing a current through the apparatus for a time, metallic copper was found to be deposited on the paper in the glass con-

taining the positive electrode. The fact seems to be that the positively charged copper ions, coming in contact with the film of ferrocyanide through which they cannot pass, give up their charges and are deposited in the metallic state; the negative $FeCy_6$ ions, accumulating on the other side of the film and there giving up an equivalent of negative electricity, are converted into triad ferrocyanide ions. At the other film the potassium ions permeating the copper ferrocyanide film, pass through it and establish electrical equilibrium by uniting with the SO_4 ions of the copper sulphate. The author thus explains Becquerel's observation that when a tube containing copper nitrate solution is placed in a solution of sodium sulphide, a deposit of copper takes place in the interior of the tube. He also shows that many electrophysiological phenomena may be explained in this way, by the action of semi-permeable materials; such for example as the secondary resistance of albumin noticed some years ago by Dubois Reymond.—*Zeitschr. physikal. Chem.*, vi, 71; *J. Chem. Soc.*, lviii, 1354, Dec. 1890. G. F. B.

5. *On Allotropic Silver.*—PRANGE has observed that after preparing, according to the method described by Carey Lea, the allotropic form of silver soluble in water, there remained in the solution a colloidal form in the dissolved state. The behavior of this solution, not only under the action of light but also at increased temperatures, has been studied by him and he finds that a separation of the dissolved silver takes place in both cases. The maximum concentration of the solution observed by the author was 4·75 grams per liter. In order to study the properties of the second modification of silver described by Carey Lea, the method of preparation was so modified as to permit of larger quantities being obtained pure in a short time. Silver nitrate solution was precipitated with ferrous sulphate and sodium citrate, the liquid decanted from the precipitate and the latter dissolved in water. On the addition of ammonium nitrate, the silver separated and was washed with water containing some ammonium nitrate. It was then filtered off, washed with alcohol and dried over sulphuric acid; all these operations being performed in the dark. The silver so prepared is no longer soluble in water. It is not entirely pure silver, though it contains no Ag_4O since on ignition it does not give up oxygen.—*Ber. Berl. Chem. Ges.*, xxiv, (Ref.) 69, Feb., 1891. G. F. B.

6. *The Continuity of Solid and Liquid;* by CARL BARUS (communicated).—Suitably adapting Kopp's well-known specific volume flask in such a way, that by means of a filament of zinc sulphate solution, the reading can be made electrically, at any temperature or pressure whatever, I obtained a method for the full and precise study of the solid-liquid volume thermodynamics. I am thus able to map out the isothermals and isopiestics, the relation of melting point and pressure, the relation of specific volumes at the melting point and pressure, together with some description of the behavior of solid matter in a suite of operations.

Working between 63° and 130°, 0 and 1900 atm., and upon naphthalene, I found that the specific volume of the liquid on the verge of solidification decreases as temperature increases, whereas the specific volume of the solid on the verge of fusion increases as temperature increases, the former variation being clearly much more marked than the latter. Hence if temperature continually increases, these loci tend to coalesce reproducing the essential feature of Andrews's classical diagram, and pointing out the occurrence of a lower or solid-liquid critical temperature in the positive region of several thousand atmospheres and several hundred degrees Centigrade. At this point liquid will pass to solid and solid to liquid without change of specific volume and obviously without volume lag. In my data the initial or stable contours of James Thomson's isothermals are also shown.

Again I found the volume lag to be pronounced in its static character. Hence the relations of solidifying point and pressure and of melting point and pressure are not identical. If a march be made in the direction of decreasing temperature, the prolonged loci tend to intersect in a region of negative external pressure. Beyond this therefore fusion takes place at a greater pressure than solidification. This I interpret as follows: the normal type of fusion changes into the ice type of fusion, through a transitional type characterized by the zero of volume lag. So far as I can now discern, the position of the transitional type for naphthalene is below 50° C., and at about —1000 atm. It is noteworthy that the normal type is reached from the ice type, in a direction of increasing temperature.

7. *Photoelectricity.*—Prof. G. M. Minchin, at a meeting of the Physical Society, Jan. 16, read a paper on the electromotive force developed by light falling on sensitive plates which were immersed in suitable liquids. The blue end of the spectrum was found to be the most effective. Currents have a photographic effect on the plates, and this action is strictly confined to the parts through which the current has passed. Comparatively strong currents were obtained from plates coated with eosine and gelatine. A Hertz oscillator restored the sensitive state in a cell placed at a distance of 81 feet. An arrangement of 50 cells in series with an electrometer was exhibited, by means of which light falling on the cells could generate sufficient e. m. f. to ring a bell or light an electric lamp.—*Nature*, Feb. 5, 1891, p. 334. J. T.

8. *Photography of Colors.*—According to M. G. Lippmann, the essential conditions for photography in colors by his method are (1) a sensitive film showing no grain; (2) a reflecting surface at the back of this film. Albumin, collodion, and gelatin films sensitized with iodide or bromide of silver, and devoid of grain when microscopically examined, have been employed. Films so prepared have been placed in a hollow dark slide containing mercury. The mercury thus forms a reflecting layer in contact with the sensitive film. The exposure, development, and fixing of the film is done in the ordinary manner, but when the operations

are completed, the colors of the spectrum become visible. The theory of the experiment is very simple. The incident light interferes with the light reflected by the mercury; consequently a series of fringes are formed in the sensitive film, and silver is deposited at places of maximum luminosity of these fringes. The thickness of the films is divided according to the deposits of silver into laminæ whose thicknesses are equal to the interval separating two maxima of light in the fringes—that is, half the wave length of the incident light. These laminæ of metallic silver formed at regular distances from the surface of the film, give rise to the colors seen when the plate is developed and dried. —*Comptus Rendus*, Feb. 2, *Nature*. Feb. 12, 1891, p. 360. J. T.

9. *Pin-hole Photography.*—Lord RAYLEIGH, in a valuable paper on this subject, discusses the subject of the definition obtainable by apertures of various diameters; and shows that a pin hole may replace a lens under certain conditions. To obtain however the definition of a lens of four inches in aperture a focal distance of five miles would be necessary. With an aperture of ·07 of an inch and a focal distance of seven feet a photograph 8 × 10 inches was taken of a group of dark trees which gave as much detail as a lens covering the the same plate. Lord Rayleigh finds the following relations, $2r^2 = f\lambda$ in which r is radius of aperture, f is focal distance and λ is wave length of light.—*Phil. Mag.*, Feb. 1891. J. T.

10. *Lectures on the Electromagnet;* by SILVANUS P. THOMPSON. 287 pp. 12mo. New York, 1891. Authorized American edition. (W. J. Johnston Co.).—Modern technical electricity may be said to rest in large measure upon the development of the electromagnet, and hence the importance of this excellent treatise from the able pen of Prof. Thompson. The volume is a small one, and the subject large, but the author has found it possible to present the matter with much fullness and completeness. The history of the electromagnet is given with an account of the early experiments of Sturgeon and Henry, and this is followed by a description of the principles involved in their construction, the various forms applicable to different purposes and their use in the many forms of mechanism in which they form an essential part. The matter was presented in four lectures delivered a little more than a year since before the Society of Arts in London, and hence the form of presentation gains that directness which exists when the speaker comes into immediate contact with his audience.

II. GEOLOGY AND MINERALOGY.

1. *Lake Bonneville;* by GROVE KARL GILBERT. Monographs of the U. S. Geological Survey, volume i, 438 pp. 4to, with 51 plates and a map. Washington, 1890.—Mr. Gilbert's history of Lake Bonneville—the largest of the Quaternary lakes of the Great Basin, of whose area it covered about one-fourth, embracing Great Salt Lake of to-day—is an admirable exposition

of a most interesting period in the geology of the western United States. This is a region characterized, as the author remarks, by a dry climate, interior drainage, and a peculiar mountain system; while its later history includes changes of climate and drainage with volcanic eruption and crustal displacement. All of these points are clearly brought out in the history of Lake Bonneville.

After a discussion of the topographic features of lake shores in general, with respect to the formation of cliffs and terraces by waves and shore currents, and related points, the author goes on to a description of the shores of Lake Bonneville, which, briefly summarized, are as follows: There is first in order of position, the Bonneville shore-line, 1000 feet above the present Great Salt Lake and embracing an area of nearly 20,000 square miles, synchronous through its whole extent; 375 feet below this is the Provo shore-line, the most strongly marked of all, when the lake area was about 13,000 square miles; between the two are the Intermediate shore-lines, while below the Provo, the slopes exhibit lake sediments with occasional shore-lines, and of these the Stansbury is the most prominent. The chronological order of these shore-lines is: (1) Intermediate, (2) Bonneville, (3) Provo, (4) Stansbury. During the period of the formation of the Intermediate embankments the water surface oscillated up and down, finally reaching its highest stage when the Bonneville shore was formed. At the level of the Bonneville shore-line, the lake had an outlet to the north through the Cache valley and Red Rock Pass into the Snake River valley. The sill of this outlet was alluvium, but when washed out to the limestone ledge, 375 feet beneath, the lake was throughout lowered to this level and this marks the position of the Provo shore-line.

A description in detail of the character of the Bonneville beds, is followed by a summary of the history of the basin. Starting from the previous arid period, the first rise of the lake was long continued and was without overflow; during this period a thick and aluminous yellow clay was deposited. Then followed a second rise of 90 feet higher, causing overflow to the north, as stated above, but this was of short duration and resulted only in the deposition of a thin calcareous white marl. As the drying of the lake went on the basin was divided into a dozen independent basins of which that of the Great Salt Lake is the largest. Since 1845 there has been a repeated rise and fall through a range of ten feet, and a very interesting part of this monograph is concerned with the discussion of the character and causes of these later changes. Connected with the changes in the level of the Lake Bonneville, as also with the parallel history of Lake Lahontan is the glaciation in the neighboring mountains, and the facts observed lead to the conclusion that the Pleistocene lakes of the western United States were coincident with the glaciers of the same district and were produced by the same climatic changes. Besides developing the history of the lakes proper, of which this is a brief outline, an account is also given in the closing

chapters of the connected volcanic eruptions, and also of the accompanying changes in continental level, for which the wide-reaching hypothesis is suggested that the disappearance of the lake and the elevation of the center of the basin stand related as cause and effect. A discussion of this subject was given by the author in this Journal in 1886 (vol. xxxi, 284). Like other recent publications by the Geological Survey, Mr. Gilbert's monograph is profusely illustrated with excellent plates, which add much to the clearness of presentation.

2. *First Annual Report of the Geological Survey of Texas*, 1889; E. T. Dumble, State Geologist. 410 pp., 8vo, with maps, plates and other illustrations.—This volume opens with "a review of Texas Geology as developed by the work of the Survey," prepared by the Director of the Survey. The rest of the volume consists of the reports of the working geologists. The "preliminary report of the Gulf Tertiary of Texas, by R. A. F. Penrose, Jr., gives an excellent account of the formations, together with economic notes on the iron ores, building stones, clays and lignites and other mineral resources of this part of the state. A brief description of the Cretaceous rocks of Texas, and their economic uses, by Robert T. Hill, follows. The brief statement in this volume is, for the most part, a résumé of the author's extensive observations. W. F. Cummings has two reports, one on the southern border of the Central Coal-field, and the second on the Permian of Texas and its overlying beds. The author dwells at length on the economic geology of the regions, besides giving some account of the formations. The next is a preliminary report on the Coal fields of the Colorado river, by Ralph S. Tarr. The author in the course of his survey arrived at important conclusions with regard to the presence of Lower as well as Upper Carboniferous beds. The views of this careful geologist are published also in the "American Geologist" for September, 1890; besides a brief note in vol. xl, of this Journal. W. von Streerawitz has a preliminary statement on the geology of Trans-Pecos, Texas, relating especially to the character of the country and its mineral resources. The last of the reports is by Prof. Theodore B. Comstock, on the "Central mineral region of Texas," and covers over 150 pages. The Central mineral region of Texas is occupied in part by Archæan rocks, and twenty-five pages of the report are devoted to them. Subdivisions of the Archæan into systems and groups are proposed, but the account shows that a careful and comprehensive study of the region is required to give them authority and we refer for them to the volume. The Paleozoic and overlying rocks of the region are also described and their orographic movements discussed. Notes follow on the metallic and other minerals, and the various economic products of the region.

3. *Geological Survey of Missouri;* A. Winslow, State Geologist.—The House, in the Legislature of Missouri, has recently voted to double the original appropriation for the survey of the State. The sum recommended is $40,000 for the year.

4. *Geological Survey of Alabama;* E. A. Smith, State Geologist.—The Survey of this State has recently issued a Report of 190 pages, on the Cahaba Coal-fields, by Joseph Squire, with an appendix on the geology of the valley region adjacent by Dr. Smith. This Report is illustrated by figures in the text, seven plates and a map of the region.

5. *Catalogues of the British Museum;* Part IV, on the Fossil Reptilia and Amphibia in the British Museum, by Richard Lydekker, published in the summer of 1890, treats of the orders Anomodontia, Ecaudata, Caudata and Labyrinthodontia. Part II, on Fossil Fishes, a volume of 568 pages and 16 plates issued the present year, contains the Acanthodii of the Elasmobranchii, the Holocephali, Astracodermi and part of the Teleostomi. Part I on Fossil Fishes appeared in 1889.

6. *The Fossil Insects of North America;* by Dr. Samuel H. Scudder, of Cambridge, Mass.—This great work has just been published by Macmillan & Co., in two quarto volumes. Volume I, treats of the Pre-tertiary Insects and contains 35 plates, volume II, of the Tertiary Insects and contains 28 plates. Only one hundred copies are issued, and half of these are already sold. Over eight hundred and fifty species are described and most of them are figured on the lithographic plates.

The descriptions include, with two or three exceptions, all the fossil insects which have ever been described from North America.

7. *Handbuch der Palæontologie herausgegeben* von Karl A. Zittel. II. Abtheilung, Palæophytologie; bearbeitet von Prof. W. Ph. Schimper und Dr. A. Schenk. München und Leipzig, 1879–1890.—The 9th and last number of this important volume of Zittel's Handbuch appeared in November, 1890, completing one of the leading contributions of the time to the science of fossil plants. Begun by Schimper in 1879 and continued by Schenk after Schimper's death in 1884, this work presents the best results of scientific research in this difficult branch of paleontology. The arrangement of the work is systematic, not geological, so that it is a botanical rather than a geological treatise, and loses, it must be admitted, much of its value from the latter point of view. Still, horizons are carefully given when known for the forms treated. The plan has been to discuss and illustrate, in the ascending order of the development of plant life, the principal vegetable types that are sufficiently well authenticated to warrant the assumption that they actually lived at the epochs recorded, and thus, by excluding all doubtful forms, to present a solid body of reliable facts bearing upon the past vegetation of the earth. It is gratifying to note that American discoveries have been carefully considered. L. F. W.

8. *Monographie der baltischen Bernsteinbäume;* von H. Conwentz. Danzig, 1890. 4°. 151 pp., 18 colored plates.—This handsome volume has the same form and typography as the preceding two on the amber flora, the first elaborated by Göppert

and Menge and published in 1883, the other begun by them but chiefly the work of Dr. Conwentz after their death, appearing in 1886. The present work is preliminary to another in preparation which is to illustrate the occurrence in amber of great numbers of cryptogamic and spore-bearing plants not hitherto treated in any of the books. But the manner in which these forms occur, chiefly as parasites or saprophytes upon or in the tissues of the amber trees, seemed to necessitate a special treatise setting forth the pathological and teratological aspects of the amber flora, and from this treatise we learn that that flora differed radically in this respect from any living flora, and that, in the language of the author "the pathologic was the rule, the normal the exception!" The treatment is in the highest degree elaborate and exhaustive, and too great praise cannot be bestowed upon the unstinted manner in which the Natural History Society of Danzig, supported by the West Prussian Provincial Landtag, has brought out these monographs. L. F. W.

9. *Ueber die Fructification von Bennettites Gibsonianus* Carr.; von H. Grafen zu Solms-Laubach. Botanische Zeitung, vol. xlviii, Leipzig, 1890, col. 789–798; 805–817; 821–833; 843–847, pl. ix, x. Also separate.—In this paper Count Solms has carefully worked over all the material from the Portland beds showing the fructification of cycadean plants, including considerable that was not known to Buckland, Robert Brown, Mantell, Corda and Carruthers at the time they published. The results reached are very important in disproving the view of Nathorst that the supposed fruiting portions are of parasitic origin, and also in showing, contrary to the theory of the Marquis Saporta relative to the progymnospermic nature of the Mesozoic Cycadaceæ, that the fruiting aggregations of Bennettites represent a relatively high type of inflorescence, reminding us rather of certain dicotyledonous types, such as that of the Compositæ or the Monimiaceæ. This interesting result is confirmatory of the law observed in so many other groups that the ancient types of vegetation advanced in their highest expressions far beyond the degree of development presented by the living forms of the same types, so that the latter have to be regarded as survivals of their earlier and not of their later stages. L. F. W.

10. *Die fossile Flora von Schönegg bei Wies in Steiermark;* von Prof. Dr. Constantin Freiherrn von Ettingshausen. I. Theil. Denkschr. d. math.-naturw. Cl. d. k. Akad. d. Wiss. Wien, Bd. LVII, Wien, 1890, 52 pp. 4 pl. Also separate.—Another rich Miocene flora has come to light in Styria to be added to those of Parschlug, Leoben, Gleichenberg, Köflach and Sotzka. The present paper contains the Cryptogams, Gymnosperms, Monocotyledons and Apetalæ, in which groups the author describes over one hundred and fifty species. The number of Cryptogams, amounting to twenty-five, is especially noteworthy, considering their paucity in other similar floras. A large proportion of the forms here enumerated had already been found in

the European Tertiaries, and of these about half occur in the lower Miocene (Oligocene) beds of Sotzka, Sagor, Häring, etc., and a few in the Eocene. L. F. W.

11. *Das australische Florenelement in Europa;* von Dr. CONSTANTIN Freiherrn von ETTINGSHAUSEN. Graz, 1890. 10 pp. 1 pl. 4°.—This is a systematic reply to various recent criticisms, particularly one by the Marquis Saporta, of the view first suggested by the author in 1850, and independently near the same time by Dr. Franz Unger, which afterwards received the sanction of Prof. Oswald Heer, that the Tertiary flora of Europe has a strongly marked Australian facies in the possession of such genera as Eucalyptus, Dryandra, Banksia, Leptomeria, Casuarina, etc. The critics deny the generic identity of these forms, and Baron von Ettingshausen has here selected some of the most striking cases and presented them anew in comparison with the living plants. Some of the cases are undoubtedly sustained, but in that of Dryandra, until something besides leaves are discovered, it will always be possible to consider the specimens as representing the genus Myrica. L. F. W.

12. *Untersuchungen über Ontogenie und Phylogenie der Pflanzen auf paläontologische Grundlage;* von Prof. Dr. CONSTANTIN Freiherrn von ETTINGSHAUSEN und Prof. FRANZ KRAŠAN. Denkschr. d. math.-naturw. Cl. d. k. Akad. d. Wiss. Wien, Bd. LVII, Wien, 1890, 36 pp. 5 pl. Also separate.—This paper follows naturally upon the series by the same authors, completed in 1889, on atavistic forms in living plants, which was preceded in 1880 by Baron Ettingshausen's memoirs on the phylogeny of plants, the whole forming a considerable body of philosophy bearing on plant development. Much of the space is devoted to a genealogical study of the oaks, illustrated by the physiotypic process, and the authors have probably made out some good cases of the actual descent of living European oaks from Tertiary forms, against the views of de Candolle, Gray, and others that they have been introduced by migrations from the north. Much that is said in the latter part of the paper on the probable mode of transition from lower to higher types of vegetation is sound and conservative, but the comparisons between ferns and dicotyledonous leaves would seem to be founded on mere accidental resemblance. The greater variability of the reproductive parts than of leaves, branches and internal structure is very properly insisted upon as an explanation of many of the facts of plant development.

L. F. W.

13. *Analysis of Alaska Garnet;* by A. F. KOUNTZE (communicated).—At the suggestion of Professor Wells, I have recently made an analysis of the well-known garnet from Fort Wrangell, Alaska. The crystals, which are dodecahedrons with edges truncated by the planes of the trapezohedron 2-2 (211), occur embedded in mica schist from which they are readily separated; they have been much admired for their almost ideal symmetry, their large size, and fine red color. The analyses are

as follows: they conform closely to the usual formula, $3RO, R_2O_3$ $3SiO_2$ and show that this garnet belongs, as was to have been expected, to the almandite or iron-alumina, variety of the species.

	I.	II.	Mean.	Molecular ratio.			
SiO_2	39·31	39·27	39·29	÷ 60=		·655	3
Al_2O_3	21·73	21·67	21·70	÷102=		·212	1
Fe_2O_3	tr.	tr.	tr.				
FeO	30·67	30·97	30·82	÷ 72=	·426		
MgO	5·22	5·30	5·26	÷ 40=	·130	·613	
CaO	1·95	2·04	1·99	÷ 56=	·035		3
MnO	1·57	1·46	1·51	÷ 71=	·022		
	100·45	100·71	100·57				
Sp. grav.	4·095	4·091					

Sheffield Laboratory, March 6, 1891.

III. Botany.

1. *The West American Oaks;* by Professor EDWARD L. GREENE, illustrated from drawings by Mr. GEORGE HANSEN, part II, San Francisco, 1890, quarto of 31 pages with 13 plates.—The first part of this extended work, already reviewed in these pages by Professor Goodale, appeared nearly two years ago, describing and illustrating more than twenty oaks of the western States, and defining several new species and varieties. As a prefatory note in part ii explains, Mr. James McDonald, through whose liberality the work is being published, became impressed with the desirability of further investigation of the new and doubtful forms described in the first part. Accordingly he generously defrayed such traveling expenses as were necessary to secure further material and information; and Professor Greene spent the summer of 1889 in studying the oaks in various parts of the west and in collecting specimens for illustration. The results of these later observations are embodied in part II and comprise a number of additions and several significant corrections to the material of the first part. Thus *Quercus McDonaldii*, Greene var. *elegantula* Greene, and *Q. Morehus* Kellogg, are now regarded as probable hybrids, while *Q. dumosa* Nutt. var. *polycarpa* Greene appears to have been founded upon an abnormal state of *Q. dumosa.* While no quality in a scientific investigator is more to be desired than perfect frankness in confessing and correcting errors, it cannot but seem that where several such corrections have to be made, so shortly after the appearance of a work, that its publication was premature. Unfortunately some of the descriptions in part ii seem no more likely to be permanent. Thus a new species is described solely from the foliage of sterile shoots. How uncertain and inexpedient such species-making is, will appear from the description itself, a part of which we may quote: "The almost orbicular general outline of the leaf, and its deep, crowded and even imbricated, doubly lobed margin are very striking peculiarities. But these are the leaves of sterile

shoots, and the low trailing shrub which the collector, in his first letter concerning it has spoken of as a "Vine Oak," so far as known bears no other kind. Nevertheless, one may dare to predict that, if the shrub is ever found in a more perfect state, the fruiting branches will exhibit leaves of a less complicated marginal indentation, and perhaps of a somewhat different general outline. In almost all our oaks, vigorous sterile shoots bear leaves far from typical."

Mr. Hansen's plates are better than those of part I by Dr. Kellogg, and give an excellent general idea of foliage and fruit. More attention could with advantage have been given to detail, and unfortunately the shading in some instances fails to give the desired effect of rotundity in the stems and acorns. B. L. R.

2. *On Isoetes lacustris* L.; by J. BRETLAND FARMER, M.A., F.L.S. (Annals of Botany, vol. v, No. xvii, pp. 37–62, pls. v, vi). —In this paper Mr. Farmer presents a series of critical notes upon the anatomy, morphology, development and systematic affinities of the common *Isoetes.* His results are in several instances at variance with those of previous observers, but are substantiated by clear illustrations, which bear every evidence of accuracy; some indeed having been reproduced from photographs. The treatment of the difficult and disputed question of the growth of the root may be mentioned as of special interest. B. L. R.

3. *Studien über die Tribus der Gaertnereen Benth.-Hook.*; by H. SOLEREDER. (Berichte der deutsch. bot. Gesellsch., viii, pp. 70–100).—The tribe of the *Gaertnereae*, as defined by Bentham and Hooker in the *Genera Plantarum*, contains the genera *Gaertnera*, *Pagamea* and *Gardneria*, and is placed in the order of the *Loganiaceæ.* The position of this small group of plants, however, is a matter of considerable doubt, and Baillon in his *Histoire des Plantes* refers these genera to the *Rubiaceæ*, with which they certainly have much in common. Dr. Solereder, seeing here an excellent opportunity to apply the "anatomical method," has made a histological study of the plants in question, with a view to determining more accurately their relationships. As a result of his researches, he concludes that the three genera cannot be classed in a single group nor indeed in the same order. *Gaertnera* and *Pagamea* he would transfer to the *Rubiaceae*, placing them near *Psychotria*, while *Gardneria* is retained among the *Loganiaceae.* The anatomical considerations upon which these conclusions are based are chiefly the presence or absence of phloem in the medullary tissue, and the occurrence of rhaphides. Neither of these features would ordinarily have much weight in classification. Internal bast occurs and fails to appear, not only in plants of the same order but in the species of the same genus, and the same is probably true of rhaphides. Nevertheless in the presence of the strong morphological resemblances of *Gaertnera* and *Pagamea* to the *Psychotriæ* the additional evidence of relationship which has been derived from the microscopic anatomy may have its value. Dr. Solereder in con-

nection with his histological studies has made a thorough examination of the morphological features as well, and has noted the fact, previously overlooked, that the ovary in the two genera just named is not strictly superior, as in the *Loganiaceæ*, but half inferior; a trait of much interest considering their supposed relationship to the *Rubiaceæ*, which have inferior ovaries. B. L. R.

4. *Ueber die Verbreitung der karpotropischen Nutationskrümmungen der Kelch-, Hull-, und ähnlicher Blätter und der Blüthenstiele;* by ANTON HANSGIRG. (Berichte der deutsch. bot. Gesellsch., viii, pp. 345–355.)—By the term carpotropic the author of this paper designates all movements of nutation which, occurring after fertilization in the flower, assist either in the protection of the young fruit or in the dissemination of the seed. These movements resemble to a certain extent other kinds of nutation, such as the nyctitropic movements, which tend to prevent too great loss of warmth by radiation, or the so-called gamotropic nutations, which directly or indirectly further fertilization; but the distinctness of their biological significance, which is at once apparent, justifies their treatment as a separate class of phenomena. The author first considers the cases of carpotropic nutations of the calyx and floral bracts. Such movements are of course confined to those plants in which these organs persist during the development of the fruit. It is by no means the case, however, that all plants with persistent calyx or bracts exhibit phenomena of the kind. As in the occurrence of other varieties of nutation, the carpotropic movements are more or less characteristic of certain groups; but they not infrequently occur, or fail to appear, quite independently of the systematic affinities of the plants. Thus although many species of *Potentilla* and *Fragaria* exhibit such movements in a pronounced form, they appear to be altogether absent in *Waldsteinia.* The first and most readily observed form of carpotropic nutation in calyx and bracts consists in their closing more or less firmly about the young fruit, undoubtedly as protective envelopes. This phenomenon Hansgirg has observed in over 150 genera of the dicotyledons and about 40 of the monocotyledons. In plants with inferior ovaries the surrounding bracts not infrequently close about the fruit, just as the segments of the calyx do in flowers with superior ovaries. Individuals of the same species have sometimes been found to vary in the extent of their carpotropic nutations. In regard to the mechanism by which these movements are brought about, the treatment is brief and provisional. The closing movements of the calyx and bracts which are to be regarded as really carpotropic are, it is stated, the result of hyponastic growth. From these the author distinguishes the purely passive movements by which a calyx, which has been dilated by the expanding corolla, closes again upon the withering of the petals. The subsequent opening of the calyx and bracts (epinastic movement) for the escape of the mature seeds has also been observed in a considerable number of cases, but is not nearly so frequent as the movement of closing.

The instances of carpotropic nutations which have been observed in the pedicels and floral axes, although fewer in number, are much more varied in character than those of the calyx and bracts. To this category Hansgirg refers such movements as tend to place the young fruit in a more protected position, and those which subsequently assist in setting the mature seeds free. As examples of the former mode of carpotropic nutation he cites the plants in which the fruit is brought, by a movement of the supporting peduncle, to rest upon the ground or even buried beneath the surface; and such aquatics as raise their flowers above water but then by a movement or curving of the peduncle draw the young fruit under the surface again. The closing of the umbel in the carrot is regarded as similar in its biological significance, and its subsequent opening is given as an example of the second sort of carpotropic movement, to secure the better dissemination of the seeds. B. L. R.

5. *The Missouri Botanical Garden;* St. Louis, Dec. 1890.—The many botanists interested in the success of the garden and school of botany at St. Louis, founded and endowed by the late Henry Shaw, are indebted to the director for a very neat and attractively illustrated volume upon the progress and condition of these institutions. Considerable space has been devoted to the life and will of Mr. Shaw, to various addresses, and an account of the first annual banquet of the trustees, presenting thus a social rather than a scientific aspect of botany; special interest, however, attaches to the official report of the director, which describes the nature of the courses of instruction that have been given, the extent of the original investigations, and the growth of the collections. Although the report is most modest in its statements, it will be apparent to every reader that the success of the garden and school has been in great measure due to the untiring energy of the director. B. L. R.

IV. Miscellaneous Scientific Intelligence.

1. *Volcano of Kilauea, Hawaii.*—A letter from Rev. E. P. Baker, dated Volcano House, March 4th, stated that the Great South Basin, Halemaumau, contained then three lakes, two besides the previously described Dana Lake, on the west side of the cone. Dana Lake was boiling up in places, and the lava, where liquid, had a flow to the westward. One of the new lakes is to the east of the cone; its condition is much like that of Dana Lake, but the flow is to the eastward. The other is to the south of the cone, and had a flow to the southward. Thus, in each, the movement of the lava is outward or away from the center of the basin.

The Daily Pacific Advertiser of Honolulu, March 12, has a report from Mr. Maby of the Volcano House that on the night preceding the 8th, the cone of Halemaumau disappeared altogether, sinking out of sight, without other great changes in Kilauea. Some light earthquakes had been felt to the south and

southwest, but none at the crater. Halemaumau had again been quietly emptied.

2. *American Association of Chemists.*—The Conference of Chemists held in Philadelphia, Dec. 30th and 31st, 1890, decided in favor of the formation of a national organization. It was resolved also that the Conference should recommend to all existing American Chemical organizations that they call a meeting of their bodies to be held in Washington in connection with the meeting of the American Association for the Advancement of Science for 1891 and that each of these organizations be requested to appoint a committee, or to continue their present committee for the further discussion of this subject.

Further, that this general Conference Committee, be called together at as early a time as practicable before the joint meeting.

It is proposed that the sub-committees shall formulate such modifications of the Constitution of the American Chemical Society as are deemed necessary to adapt it to the requirements of the Association proposed. Also, that the chairmen of these sub-committees shall then, so far as possible, harmonize the views embodied in these reports of their several organizations and shall have printed for presentation at the joint meeting a report, or majority and minority reports, on a Constitution for the proposed Association of American Chemists.

The Chairman of this Conference, with Professors Clarke and Hale, were appointed a committee to select time and place for the meeting of the general Conference Committee.

3. *Audubon Monument.*—A committee with reference to the erection of a monument to the memory of AUDUBON has been appointed by the New York Academy of Sciences, and a design has been prepared, the execution of which, it is estimated, will cost about $10,000. An appeal is made in a circular to the lovers of science in behalf of it, with the hope that the monument may be erected in the fall of 1891. At present the remains of the great naturalist are in Trinity Cemetery, New York City, without a monument over them. Dr. Thomas Egleston is chairman of the committee and Dr. N. L. Britton secretary and treasurer.

Maximum Stresses under concentrated Loads treated graphically by Henry T. Eddy, 100 pp. with a folding plate. New York (D. Van Nostrand Co.—reprinted from the Trans. Amer. Society Civil Engineers).

The Physicians Visiting List (Lindsay & Blakiston's) for 1891. Fortieth year of its publication. Philadelphia (P. Blakiston, Son & Co.) 1891.

OBITUARY.

ALEXANDER WINCHELL.—Prof. Winchell, acting President of the Geological Society of America at its last meeting in December, and President-elect for the year now passing, died on the 19th of February at Ann Arbor, Michigan. He was born Dec. 31st, 1824, in the town of Northeast, Dutchess Co., N. Y., and graduated at the Wesleyan University, at Middletown, Conn.

In 1854 Mr. Winchell accepted the professorship of Physics and Civil Engineering in the State University of Michigan, at

Ann Arbor, and the following year was transferred to that of Geology, Zoology and Botany. From 1873 to 1879 he was first Chancellor of the University at Syracuse, N. Y., and afterward Professor of Geology and the Natural Sciences in the same University and in the Vanderbilt University of Tennessee. In 1879 he returned to Ann Arbor, taking again the chair he had left, and there remained in active service until his decease.

The subjects of Professor Winchell's publications were various; but his scientific investigations were confined to the departments of Geology and Paleontology. In 1859 he was appointed Director of the Geological Survey of the State of Michigan; and in 1860 he sent to the Legislature his "First Biennial Report," which was published in 1861. The survey was soon after suspended in consequence of the civil war. It was resumed under his charge again in 1869, but two years after he resigned the position. He however published, before this and later, occasional papers bearing on the geology of the State and its mineral resources, besides a geological map of Michigan, and also the results of some observations in other States.

During the later years of Professor Winchell's life his geological work was largely among the Archæan rocks, and especially those of Minnesota, in connection with the survey which was in progress under his brother, Prof. N. H. Winchell, and his reports appear in the annual volumes of the survey. These important contributions to Archæan geology are collected in a volume of more than 500 pages issued by him in 1889, entitled "Field Studies of the Archæan Rocks." "A last word with the Huronian" is the title of a paper read by him before the American Geological Society on the 30th of last December. "The Origin of the Earth's features" was another subject on which he wrote at some length; and in 1885 he presented to the American Association for the Advancement of Science a valuable paper on "The sources of trend and crustal surplusage in mountain structures," the substance of which is published in vol. xxx (1885) of this Journal. In 1886 appeared a Geological Text Book under the title of "Geological Studies," or Elements of Geology, which contains many of his personal observations.

Professor N. H. Winchell's tribute to his brother in the American Geologist for March, rightly says: "He was a man of indomitable will, unremitting industry, with an insatiable love for work in his profession; of broad philanthropy, of penetrating reason, of fearless pursuit of the truth; at home in any realm of nature's handiwork,—which he considered permeated with the essence and will of its Creator; a geologist who embraced geology in all its ramifications, ambitious to serve the world by contributing to its fund of advanced knowledge."

Henry Bowman Brady.—Dr. Brady, the eminent British authority on the Foraminifera, died on January 10th. He was born at Gateshead-on-Tyne, February, 1835.

APPENDIX.

ART. XXXIX.—*Restoration of Triceratops;* by O. C. MARSH. (With Plates XV and XVI.)

IN previous numbers of this Journal, the writer has given the principal characters of the gigantic *Ceratopsidæ*, or horned Dinosaurs, from the Laramie, with figures of the more important parts of the skull and skeleton.* The abundant material now available for examination makes it possible to attempt a restoration of one characteristic form, and the result is given in Plate XV. This figure, about one-fortieth of natural size, is reduced from a large outline plate of a memoir on this group, now in preparation by the writer for the United States Geological Survey.

This restoration is mainly based on two specimens. One of these is the type of *Triceratops prorsus*, Marsh, in which the skull, lower jaw, and cervical vertebræ are in remarkable preservation. The other specimen, although somewhat larger, is referred to the same species. It consists of parts of the skull, of vertebræ, the pelvic arch, and nearly all the important limb bones. The remaining portions are mostly taken from other remains found in the same horizon and localities, and at present are not to be distinguished specifically from the two specimens above mentioned. The skull as here represented corresponds in scale to the skeleton of the larger individual.

In this restoration, the animal is represented as walking, and the enormous head is in a position adapted to that motion. The

* This Journal (3), vol. xxxvi, p. 477, December, 1888; vol. xxxvii, p. 334, April, 1889; vol. xxxviii, p. 173, August, 1889, p. 501, December, 1889; vol. xxxix, p. 81, January, 1890, p. 418, May, 1890; and vol. xli, p. 167, February, 1891.

massive fore limbs, proportionally the largest in any known Dinosaur, correspond to the head, and indicate slow locomotion on all four feet.

The skull is, of course, without its strong horny covering on the beak, horn-cores, and posterior crest, and hence appears much smaller than in life. The neck seems short, but the first six cervical vertebræ are entirely concealed by the crest of the skull, which in its complete armature would extend over one or two vertebræ more. The posterior dorsals with their double headed ribs continue back to the sacrum itself, there being no true lumbars, although two vertebræ, apparently once lumbars, are now sacrals, as their transverse processes meet the ilia, and their centra are coössified with the true sacrum. The four original sacral vertebræ have their neural spines fused into a single plate, while the posterior sacrals, once caudals, have separate spines directed backward.

No attempt is made, in this restoration, to represent the dermal armor of the body, although in life the latter was more or less protected. Various spines, bosses, and plates, indicating such dermal armature, have been found with remains of this group, but the exact position of these specimens can, at present, be only a matter of conjecture.

This restoration gives a correct idea of the general proportions of the entire skeleton in the genus *Triceratops.* The size, in life, would be about twenty-five feet in length, and ten feet in height. The genus *Ceratops* so far as at present known is represented by individuals of smaller size, and in some instances, at least, of quite different proportions. A third genus, which may be called *Sterrholophus*, can be readily distinguished from the other two by the parietal crest, which had its entire posterior surface covered with the ligaments and muscles supporting the head. In *Ceratops* and *Triceratops*, a wide margin of this surface was free, and protected by a thick, horny covering. The type of the new genus is the specimen described and figured by the writer, as *Triceratops flabellatus*, which in future may be known as *Sterrholophus flabellatus*, Marsh. There is some evidence that other forms, quite distinct, left their remains in essentially the same horizon of the Laramie, but their true relation to the above genera cannot be settled without further discoveries.

This group so far as at present investigated is very distinct from all other known Dinosaurs, and whether it should be regarded as a family, *Ceratopsidæ*, as first described by the writer, or as a sub-order, *Ceratopsia*, as later defined by him, will depend upon the interpretation and value of the peculiar characters manifested in its typical forms.

The main characters which separate the group from all other known families of the *Dinosauria* are as follows:

(1) A rostral bone, forming a sharp, cutting beak.
(2) The skull surmounted by massive horn-cores.
(3) The expanded parietal crest, with its marginal armature.
(4) A pineal foramen.
(5) The teeth with two distinct roots.
(6) The anterior cervical vertebræ coössified with each other.
(7) The dorsal vertebræ supporting, on the diapophysis, both the head and tubercle of the rib.
(8) The lumbar vertebræ wanting.

The animals of this group were all herbivorous, and their food was probably the soft succulent vegetation that flourished during the Cretaceous period. The remains here figured are from the Ceratops beds of the Laramie, and were found by Mr. J. B. Hatcher, in Wyoming, on the eastern slope of the Rocky Mountains.

Restoration of Brontosaurus.

On Plate XVI is a restoration, one-ninetieth natural size, of another large Dinosaur, the gigantic *Brontosaurus* of the Jurassic. This differs so widely from *Triceratops* of the Cretaceous that a comparison of the two is most instructive. Each represents the dominant reptilian type of the period in which it lived, and each belongs to a distinct order of the *Dinosauria.* The older form, *Brontosaurus*, was more than double the size of the later *Triceratops.* The former represents a more primitive type, and the latter, one highly specialized. Both show the early character of locomotion on all four feet, which many allied forms of each appear to have nearly or quite lost before their extinction.

In the restoration of *Brontosaurus*, the diminutive head will first attract attention, as it is smaller in proportion to the body than in any reptile hitherto known. The neck was very long and flexible. The body was rather short. The legs and feet were massive, and the bones all solid. The tail was very long and powerful. The animal during life must have been nearly sixty feet in length, and about fifteen feet in height. Its probable weight was more than twenty tons.

Brontosaurus was herbivorous in habit, and its food was probably aquatic plants or other succulent vegetation. The skeleton here represented was found in the Atlantosaurus beds of the upper Jurassic, in Wyoming, west of the Rocky Mountain range.

The figure on Plate XVI, one-ninetieth natural size, is reduced from a large restoration, one-twenty-fourth natural size, on a lithographic plate accompanying the monograph of the *Sauropoda*, prepared by the writer for the U. S. Geological Survey. In previous numbers of this Journal will be found various papers by the writer on this group of Dinosauria, and among them, published in August, 1883, is a preliminary outline sketch of the present restoration.

New Haven, Conn., March 18th, 1891.

Explanation of Plates.

Plate XV.—Restoration of *Triceratops prorsus*, Marsh; one-fortieth natural size. (Cretaceous.)

Plate XVI.—Restoration of *Brontosaurus excelsus*, Marsh; one-ninetieth natural size. (Jurassic.)

ART. XL. — *Development of the Brachiopoda.* Part I. Introduction; by CHARLES E. BEECHER, Ph.D. (With Plate XVII.)

THE Brachiopoda have been so carefully studied, that any new general conclusions regarding them must naturally be based upon features not heretofore considered. In other classes of animals, such important results have recently been reached by the application of the law of morphogenesis as defined by Hyatt, that the writer was led to study the Brachiopoda from this standpoint. The facts observed by this method are mainly new to the class, and considerably affect the taxonomic positions and affinities of the various families and genera.

The value of the stages of growth and decline in work relating to phylogeny and classification is now generally admitted. The memoirs of Hyatt, Jackson, and others, amply show that the clearest and simplest understanding of a group may thus be reached. The application of the principles of growth, acceleration of development, and mechanical genesis, form the main factors in the studies here made. The geologic sequence of genera and species in this connection is also of the greatest importance, for in this way the development of ancient species may be studied, which in their adult condition represent nealogic or nepionic stages of later forms.

The prolific development of the Brachiopoda, both in point of numbers and variety of genera and species, together with their geological history, mark this group as one which should furnish important data for the study of its genesis and of the limits of a specialized variation in a single class. Moreover, as its culmination was reached in paleozoic time, the group should afford illustration of many principles of evolution.

The main characters common to the class of Brachiopoda are as follows: the bivalve shell; the pedicled or fixed condition; the animal composed of two pallial membranes intimately related to the shell; a visceral sac; and two arms or appendages near the mouth. The extreme range of variation does not eliminate any of these features, and, consequently, no univalve or multivalve forms are found, nor any strictly free swimming species, nor growths or modifications adapting the organism to a pelagic life. Thus, the limits of modification are narrowly restricted as compared with those of several other classes, i. e. the Echinodermata and the Pelecypoda, but the thousands of known species of Brachiopoda show what differentiation has taken place within these limits.

The Protegulum.

The first important observation to be noted is, that all brachiopods, so far as studied by the writer, have a common form of embryonic shell, which may be termed the *protegulum*.* The protegulum is semicircular or semielliptical in outline, with a straight or arcuate hinge line, and no hinge area. A slight posterior gaping is produced by the pedicle valve being usually more convex than the brachial. The modifications noted are apparently due to accelerated growth, by which characters primarily nealogic become so advanced in the development of the individual as to be impressed finally upon the embryonic shell. This feature is well shown in the development of Orbiculoidea and Discinisca, and is reserved for discussion under these genera.

As the protegulum has been observed in about forty genera† representing nearly all the leading families of the class, its general presence may be safely assumed. In size it varies in different genera and species. The range is from ·05 to ·60^{mm}. A similar range in the prodissoconch of pelecypods has been noticed by Dr. Robert T. Jackson. The protoconch of cephalopods and gastropods also varies greatly. In all these classes, the size of the initial shell has no special relation to the mature form, and it seems to have little significance in related genera or species.

The structure of the protegulum has been described as corneous and imperforate. In all probability it is the same for the entire class, whether among the corneous and phosphatic linguloids and discinoids, or the terebratuloids and other forms having carbonate of calcium shells. Professor E. S. Morse, in describing the early stages of Terebratulina,‡ says: "A heart-shaped corneous shell is formed even at this early stage, for in several cases I met with it where the softer portions had been removed by Paramæcia." Similarly, in the genus Cistella according to Kowalevski:§ "En même temps la coquille se forme, par suite du dépôt sur la cuticule chitineuse des minces couches de calcaire, dans lesquelles on ne voit point encore les perforations tubulaire." Previous to this stage,

* From πρώ, early, and τέγος, a covering.

† Atretia (Cryptopora), Chonetes, Cistella, Conotreta, Crania, Craniella, Discina, Discinisca, Glottidia, Gwynia, Kraussina (Megerlina), Laqueus, Leptæna, Lingula, Lingulops, Linnarssonia, Liothyrina, Magellania (Macandrevia), Martinia, Muhlfeldtia, Obolus? Œhlertella, Orbiculoidea, Orthis group, Pholidops, Productella, Rhynchonella (Hemithyris), Schizambon, Schizobolus, Schizocrania, Schizotreta, Spirifer, Streptorhynchus (Orthotetes), Stropheodonta, Strophomena, Terebratella, Terebratulina, Thecidium (Lacazella), Trematis, Tropidoleptus, Zygospira.

‡ Embryology of Terebratulina. Mem. Boston Soc. Nat. Hist., vol. ii, p. 257, vide figures 68, 76, pl. viii. 1873.

§ Developpement des Brachiopodes, Kowalevski. Analyse par MM. Œhlert et Deniker, pp. 65, 67. 1883.

"Les lobes du manteau commencent alors à se recouvrir d'une cuticule épaisse et rigide que ne leur permet plus de se mouvoir que dans le sens vertical."

From the minuteness and the tenuous nature of the protegulum, its fossil preservation in an unaltered condition would not be anticipated. Neither would it be found on the beaks of mature shells, whether recent or fossil. In rare cases of unusually perfect conservation of the beaks, the protegulum is retained, but frequently its form and characters are exhibited after its removal, by the impression left in the surrounding calcareous test. To study the features of the protegulum, and the early stages in the growth of the shell, it is very desirable and often necessary to have young and well-preserved specimens. The rapid encroachment of the pedicle on the ventral beak commonly obliterates, at an early period, all traces of the protegulum and early nepionic stages. While in the brachial valve, abrasion from foreign objects, or against the deltidial covering, or the pedicle itself, usually removes all early lines of growth or nepionic characters. In general, fully matured shells, recent or fossil, do not furnish material for a study of the incipient growth stages.

Affinities.—In looking for a prototype preserving throughout its development the main features of the protegulum, and showing no separate or distinct stages of growth, the early primordial form hitherto known as Kutorgina, Billings, is at once suggested. This genus, as shown below, includes two distinct types, for one of which the name Paterina is proposed.*

* The strict definition of Kutorgina limits it to calcareous shells, such as are found near Swanton, Vermont, often occurring as casts in the limestone. The original description of *Obolella cingulata* by Billings (Geology of Vermont, vol. ii, p. 948, figs. 347–349, 1861) seems to include two species. One, represented by figures 347 and 349 (loc. cit.), agrees with phosphatic species having a straight hinge line as long as the width of the shell. The other, shown in figure 348, has a calcareous test, shorter hinge, flattened brachial valve, and convex pedicle valve with arching beak. Upon the latter species, the genus was founded, and it has been recognized as the type by C. D. Walcott (Bulletin U. S. Geol Surv., No. 30, p. 102, pl. ix, figs. 1, 1*a*, *b*, 1886.) The species represented by Billings in figures 347 and 349 resembles *Obolus labradoricus* (fig. 345, loc. cit.), and is represented by Walcott (l. c, pl. ix, figs. 2, 2*a*, *b*) and referred by him also to Kutorgina. Mr. Walcott recognizes two groups of species, which are classified (p. 102) as: "shell structure calcareous (*K. cingulata*, *K. Whitfieldi*) or horny (*K. Labradorica*, *K. sculptilis*)."

An examination of specimens representing both groups, leads the writer to consider *Kutorgina cingulata* and *Obolus labradoricus* of Billings as generically distinct. Therefore the name *Paterina* is here proposed to include species of the type of *Obolus labradoricus.* This name is intended to express the primitive ancestral characters which it possesses, Plate XVII, figures 1, 2. Exfoliated specimens of *Paterina labradorica* show a roughened area on the cast, each side of the median line near the beak. These probably represent muscular attachments. Sections of the shell show no hinge area as described in *K. cingulata.* A study of the latter would doubtless present distinct stages of growth. The

The valves of Paterina are subequal, the pedicle valve being a little more elevated than the brachial. They are semielliptical in outline. In mature specimens, all lines of growth, from the nucleal shell to the margin, are unvaryingly parallel and concentric, terminating abruptly at the cardinal line. In other words, no changes occur in the outlines or proportions of the shell during growth, through the nepionic and nealogic stages up to and including the completed ephebolic condition. The resemblance of this form to the protegulum of other brachiopods is very marked and significant, as it represents a mature type having only the common embryonal features of other genera. It is of further importance as representing, in many species, an early condition of nepionic growth subsequent to the protegulum, during which the proportions and features of the shell undergo no modification except increase in size. This is termed the *paterina stage.* It is well shown in the brachial valve of *Orbiculoidea minuta*, Hall, Plate XVII, figure 5.

Modifications from acceleration.—The modifications in the form of the protegulum are due to the influence of accelerated growth, by which nepionic and sometimes nealogic features are pushed forward, or appear earlier in the history of the individual, so as to become impressed upon the early embryonic shell. Only a brief review of these changes will be noted here, as a fuller description properly belongs under the discussions of the various genera and families. Naturally, the greatest departure from the normal protegulum is exhibited in the most variable and specialized valve, the pedicle valve. The nearly equivalve genera, as Lingula and Glottidia, present almost no modification. In the ventral valve of Linnarssonia and Orbiculoidea (Plate XVII, fig. 7), the protegulum has a hinge more or less arcuate. Discinisca shows a subcircular pedicle protegulum with a pedicle notch, and the evidence of any hinge in the brachial is very slight, Plate XVII, figures 8, 9. The discinoid character appearing in the second and third nepionic stage of the paleozoic Orbiculoidea (Plate XVII, fig. 6), has become so accelerated in neozoic and recent Discinisca as to produce a discinoid protegulum.

The strophomenoid shells usually retain a normal protegulum in the brachial valve, but from the acceleration of the discinoid stage in the pedicle valve, the protegulum has an abbreviated hinge and arcuate hinge line, Plate XVII, figures 13, 14, 15.

dissimilar valves, arcuate ventral beak, and mesial depression, could be developed only by passing through several well-marked phases. This in itself seems sufficient for a separation were no other characters present.

No marked variation has yet been observed among the spire bearing genera, nor has any been seen in the terebratuloids or rhynchonelloids further than the radii on the protegulum of Atretia (Cryptopora). Possibly this feature in Atretia is an inheritance from the radiate character of the shell in the Rhynchonellidæ. It may be, however, one of the features consequent upon its fragile nature and deep sea habitat, as observed among other abyssal shells.

Differences in the Valves.

The dissimilarity in the form and relations of the two valves progressively increases in the following genera: Lingula, Terebratulina, Cistella, Discinisca, Thecidium (Lacazella), and Crania. Lingula is nearly equivalve, both valves bearing a close resemblance to each other. In Terebratulina and Cistella, the two valves are more strongly specialized, while in Discinisca, Thecidium, and Crania, they are quite unlike.

Two important organic characters accompany and partake of a similar amount of variation; (*a*) the length and direction of the pedicle, and (*b*) the position and structure of the pedicle opening. Lingula with a long, fleshy, mobile pedicle receives uniformly disposed axial impacts on the valves, and, therefore, with equal physiological reactions, equality in size and form is produced. Terebratulina and most of the other terebratuloids and rhynchonelloids have a shorter and less flexible pedicle. As a whole the motions of the animal are more restricted; the pedicle opening is confined mainly to one valve; the valves, consequently, are differently related to the environment, and express this difference in their dissimilarity. In these examples, also, the inclination of the pedicle to the longitudinal axis, or of the shell to the surface of support, agrees, *pari passu* with the amount of unlikeness in the valves, except when the pedicle is so shortened as to interfere with their free movement. To this inclination is probably due the difference in the action of the forces from without.

Normally, in Lingula, the pedicle is in direct linear continuation with the axis of the shell. Terebratulina and Magellania are inclined at an angle of 40° to the surface of support, but in Cistella and Muhlfeldtia, this is increased to about 70°. In the latter genera, although the position of the axis is nearly vertical, the shortening of the pedicle precludes more than a slight elevation and rotation of the organism. The more the pedicle opening is confined to one valve the greater is the difference between both.

Passing to Discinisca, the pedicle is found to be at right angles to the longitudinal axis, and the valves become strictly an upper and a lower. The lower rests upon the

object of support, and the animal is capable of raising and rotating it only to a slight degree. Under such circumstances, the lower valve is wholly different in its relations to the environment, and, naturally, it expresses the greatest dissimilarity in the two valves of any genus yet discussed. In some allied genera, as Discina (type *D. striata*) and Schizotreta, where the pedicle is small and the lower valve rises above the object of support, a similar form in both valves is again produced by the conical growth of the lower valve.

More primitive types, as Acrotreta and Acrothele, having the plane of the brachial valve at right angles to the direction of the pedicle, retain a marginal upper beak, while the lower is elevated, subcentral, and perforate. These features in Acrotreta and Discina resemble, in a measure, those in the rudistes. In Acrotreta as in Caprotina, the upper valve shows its normal affinities, while the other has become highly modified and dissimilar. But in Discina and Hippurites, the hinge line is lost, and the apex of the upper valve is subcentral. This conical habit of growth in erect attached organisms has been explained as the physiological reaction from equal radial exposure to the environment. It constitutes the law of radial symmetry, ably discussed by Haeckel, Jackson, Korshelt, and Heider. Its application to the Brachiopoda can be made mainly in forms having the pedicle perforation subcentrally located in the lower valve.

In Thecidium and Crania, the calcareous union of the lower valve to the object of support represents the extreme of unlike conditioning, and such forms exhibit the greatest difference in the features of the opposite valves. Crania being probably derived from discinoid stock is without proper hinge. In the history of its development, so far as known, it does not show beyond the protegulum, an early hinged condition. Hence there is no indication of direct derivation from hinged forms. A false hinge is sometimes present, but it clearly shows a secondary mechanical adaptation, and not a phylogenetic character. On the other hand, true hinged attached genera, such as Thecidium (Lacazella), Davidsonia, and Strophalosia, possess this feature as a later ancestral character, and, in their chronological history, tend to shorten and gradually eliminate it. An illustration of this is seen in the succession of the species in Strophalosia, or in the ontogeny of one of the Permian species. *Strophalosia Goldfussi*, in early nealogic stages, has a hinge line about equal to the width of the shell, but in mature individuals, it is usually less than one-half the width. This reduction of the hinge and ostrean form of growth are in accordance with the deductions and observations made upon the Oyster and its allies by Jackson, and the mechanical principles are evidently the same in both cases.

One of the most conspicuous examples of a difference in the form of the valves is shown in the abnormal genus Proboscidella. In early nealogic stages, it resembles an ordinary Productus. Afterwards, probably from burrowing in the mud, the ventral valve becomes extravagantly developed anteriorly into a calcareous tube. This is accomplished by the excessive growth of the anterior and lateral margins. Then an infolding takes place until the lateral edges unite, after which the tube is built up by concentric increment around the free end. The resemblance of Proboscidella to Aspergillum is quite marked, except that, in the latter genus, the tube is formed from the growth and union of two valves instead of one.

From the morphological differences of the pedicle and brachial valves, it will be seen that the highest modifications occur in the former; while the variations in the latter are expressed mainly as adaptive reactions or accommodations to these changes. The explanation of the fact that greater alteration takes place in the pedicle valve evidently lies not in the greater plasticity of this member, but in its more highly specialized and differentiated external form, and mainly in its being the lower and attached valve.

No account is taken here of the crura, loops, and spires of the brachial valve, so characteristic and important in many families and genera. These are evidently processes developed by the internal requirements of the animal and are not affected by the environment. Therefore, they are internal calcified organs independent of the form or manner of growth of the external covering. This is shown by the fact, that, in each group, there is a frequent recurrence of similar general external features, whether in crurate, looped, or spire bearing genera.

Genesis of Form.

The principal characters shared by the two valves are the general outline and the hinge. In typical and generalized forms, as Lingula, Terebratulina, Cistella, and Discinisca, considered as before in regard to length of pedicle, freedom of movement, and direction of longitudinal axis to the object of support, we find a key to these types of structure. In the individual development of Terebratulina, as shown by Morse, we first have the early embryonic shell (protegulum), with a short pedicle and straight hinge. The next stage retains both these characters, but the valves have become more unequal and the pedicle opening confined to the fissure of one valve. The result is a shell very much like Argiope or Megerlia (Megathyris and Muhlfeldtia), to which

Professor Morse also called attention. The same author next showed that the succeeding stage had a comparatively long pedicle, and a shell linguloid in form. Afterwards, the defining of the pedicle opening, shortening of the pedicle and truncation of the ventral beak, produced the final characteristic external features of Terebratulina. The deduction from this example and from Lingula is, that genera having pedicles sufficiently long to admit of freedom of axial movement have elongate and rostrate shells. The shortening of the pedicle brings the posterior part of the shell in more or less close proximity to the object of support, and, as growth cannot take place in that direction, it increases laterally, resulting in broader forms with extended hinge areas, as in many species of Cistella, Scenidium, Muhlfeldtia, Terebratella, Kraussina, etc.

The variety known as *Muhlfeldtia truncata*, var. *monstruosa*, Davidson, further shows how discinoid characters may be produced in an entirely different type of shell. A specimen was found by the writer in a position which readily gave the solution to its variation from the normal species. It was attached to a foreign object under the hinge line of a large mature specimen of *M. truncata*, thus forcing the axis and plane of the valves into parallelism with the object of support. In this way, the pedicle emerged at right angles to the axis. The growth of the shell and the increase in the size of the pedicle caused the latter to encroach on the substance of the lower beak, forming a dorsal perforation or pedicle-notch, which in this example amounted to an arc of 180°. As the ventral valve was the upper and the dorsal the lower, with the pedicle opening through the latter, only the abnormal position of the shell can account for this anomalous discinoid condition. In the development of Orbiculoidea, a true discinoid genus, it will be seen that during the early stages it had a straight hinge and marginal beaks, Plate XVII, figures 5, 6, 7. Then, from its procumbent position and peripheral growth, the pedicle became more and more enclosed by the lower valve, until in Schizotreta (fig. 11) and Acrothele (fig. 12), the opening finally became subcentral.

The resemblance between this form of growth and habit and Anomia is very suggestive. Morse and Jackson have shown, that from an early normal, bivalve, hinged shell, the right valve, in its subsequent growth surrounds the byssus, which occupies much the same position and performs a function similar to the pedicle of Discinisca and Orbiculoidea. Peripheral growth also causes the initial shell to recede from the margin. Another instance is thus furnished of a discinoid habit in an organism otherwise entirely different. It is there-

fore evident, that the discinoid form is purely due to the mechanical conditions of growth. Hence the writer believes, that any bivalve shell with the plane parallel to the object of support, and attached by a more or less flexible, very short organ, as a byssus or a pedicle, without calcareous cementation, assumes a discinoid mode of growth.

The conditions of radial symmetry and ostrean growth were briefly mentioned in a preceding section, and need only be cited here as resulting from the cemented state of fixation, as shown in species of Thecidium, Strophalosia, and Crania.

A long pedicle accompanies elongate shells with short hinges. A short pedicle causes extended hinge growth when the plane of the valves is ascending or vertical, but a discinoid form results when the plane of the valves is horizontal.

Types of pedicle openings.

M. Deslongchamps is one of the few writers who have given much consideration to the characters of the pedicle opening. His studies, although mostly confined to the terebratuloids and later spire bearing genera, conclusively show the importance of this feature.* In a recent paper by the writer,† attention was called to the persistence and embryonic features of this portion of the shell. "It has been shown by J. M. Clarke and the writer, that all species, so far as examined, possessing a true deltidium in the adult state, show that it was gradually developed in early stages of growth, by concrescence along the lateral margins of an open triangular area. Also, that all species furnished with a pedicle-sheath have it fully developed in the earliest growth-stages which have been observed for these species, and the subsequent growth of the individual does not materially alter its general characters, except that it is sometimes retrogressive, the parts becoming atrophied or functionally obsolete. A feature of such importance, and so intimately connected with the embryonal growth of the shell, must be given considerable significance in discussing the various genera in which it is present or absent." At that time, the development and true interpretation of these different features of the pedicle opening and the early stages of the shell had not been studied sufficiently, and a more general application of the principles involved could not then be made. The results of later studies give prominence to these characters, and show that they furnish a method for an ordinal grouping of the genera of brachiopods. This is found to agree with the chronological

* Note sur le développement du deltidium chez les brachiopodes articulés. Bull. Soc. Géol. France. 2e Ser. T. XIX, pp. 409–413, pl. IX, 1862.

† This Journal, vol. xl., p. 217, Sept. 1890.

history of the class, as well as with the anatomical and shell characters, and therefore it is believed to be a natural and reliable subdivision.

The first and simplest type of pedicle opening is in shells with a posterior gaping of the valves, through which the pedicle protrudes in line with the axis. It is shared more or less by both valves, although, generally, the greater portion of the periphery is included by the pedicle valve. The genera Paterina and Lingula afford types of this form of pedicle opening.

The second type is characterized by a pedicle wholly confined to the lower valve, and emerging at right angles to the plane of the valves. In primary forms, it is not entirely surrounded by shell growth, but occupies a sinus, slit, or fissure. A further specialization carries it quite within the periphery, and it finally becomes subcentral. A serial illustration of this type is presented in the genera Schizocrania, Orbiculoidea, Discinisca, Schizotreta and Acrothele. The group probably terminates with forms like Crania and Pholidops, as shown by the development of the brachial valve and from internal characters. The development of the lower valve, however, has not been observed as yet in either of these genera.

The third form is an accelerated derivative of the second. During the first nepionic stage of shell growth, the pedicle is enclosed by the substance of the ventral valve. The perforation remains submarginal, and does not tend to become centralized as in the preceding group. The initial pedicle opening may be maintained by further growth, forming a pseudodeltidium; or it may be merged into the hinge opening by resorption of the shell or by pedicle abrasion. Orthisina, Leptæna, Strophomena, Chonetes, and Stropheodonta furnish illustrations of the first condition, and the second is represented in Tropidoleptus and in the groups of Orthis.

The fourth type in its incipient stage marks a return to the simple conditions of the first, but in early nepionic stages the pedicle is confined to the ventral beak, and deltidial plates are developed in the majority of species. These plates at maturity may entirely limit the pedicle opening below, so that the pedicle emerges immediately under the beak, or encroaches upon the substance of the beak itself. This type of opening is shown by Zygospira, Spirifer, Rhynchonella, Terebratulina, Magelliana, etc.

The only divisions of the class which have had continued existence are the Arthropomata and Lyopomata, proposed by Owen in 1858.* Subsequently, various authors gave names to

* Encycl. Brit., 8th ed., vol. xv, p. 301, 1858.

express other characters, but all included the same elements in the two divisions. Professor Huxley's terms, the Articulata and Inarticulata, have also come into current use, and are convenient to express the nature of the union of the valves. All the names proposed for these divisions by Owen, Bronn, Huxley, Gill, and King, are based upon (1) the intestinal canal whether ending in an anus or in a blind sac, (2) the relative proportions of the viscera and brachia to the shell cavity, and (3) the character of the union of the valves.

If, as Agassiz has said,* orders should be founded upon facts of development or embryology, the ordinal division into groups expressing the genesis of an important common character should furnish a satisfactory classification. The Articulata and Inarticulata do not appear to have a primary developmental basis in nature. These names may be conveniently retained as two divisions or sub-classes, but they fail to express the true relationships of the various groups included in them.

In 1883, Dr. Waagen (Palæontologia Indica) proposed a classification comprising six suborders, founded partly on the pedicle opening and on the form of the brachial supports. Two of his groups, the Mesokaulia and Aphaneropegmata, are nearly equivalent in extent to the Atremata and Protremata now proposed. Daikaulia and Gasteropegmata of Waagen are here included in the Neotremata, and the Telotremata comprise the Kampylopegmata and Helicopegmata of the same author. With the transfer of some genera in his suborders, they may properly be recognized and serve further to differentiate the class into comprehensive groups.

After this preliminary discussion, the four groups proposed can be defined and understood. The special details with full illustration and demonstration of the development and affinities in each group are left for future consideration. At present it is aimed to give only the general results which have been reached through the study of individual development (ontogeny) among various species representing the families of nearly the entire class. Of the sixteen families of Brachiopoda recognized by Œhlert in Fischer's "Manuel de Conchyliologie," fifteen have thus been studied and determined. The genera marked by an asterisk have been examined somewhat in detail. The others have been investigated partly from adult specimens, and from the published descriptions of the genera.

* Methods of Study in Natural History, L. Agassiz. 8th ed., p. 76, 1873.

Atremata.

(α, priv., and τρῆμα, perforation.)

Plate xvii, figures 1–4.

Protegulum semicircular or semielliptical; hinge line straight or slightly arcuate. Growth taking place mainly around the anterior and lateral margins, never enclosing or surrounding the pedicle, which in all stages emerges freely between the two valves, the opening being more or less shared by both. Valves inarticulate.

Including the genera:

Dignomia.	*Leptobolus.	Obolus.
Dinobolus.	*Lingula	*Paterina.
Elkania.	Lingulasma.	Paterula.
Glossina.	*Lingulops.	Rhynobolus.
*Glottidia.	Monomerella.	Trimerella.
Lakhmina.	Obolella.	

Neotremata.

(νεός, young, and τρῆμα, perforation.)

Plate xvii, figures 5–12.

Protegulum as in the preceding order in primitive forms, becoming more circular, and with shorter and more arcuate hinge in the pedicle valve of derived types. Growth of the brachial valve tending to become peripheral. In the opposite valve, the pedicle more or less surrounded by progressive nealogic growth posterior to the initial hinge. Pedicle fissure remaining open in primitive mature forms, becoming enclosed in secondary forms during nealogic stages, and in derived types enclosed in early nealogic or nepionic stages. Valves inarticulate.

Including the genera:—

Ancistocrania.	*Discinopsis.	*Orbiculoidea.
Acrothele.	Helmersenia.	Pseudocrania.
Acrotreta.	Iphidea.	*Rœmerella.
*Conotreta.	Kayserlingia.	*Schizambon.
*Crania.	Lindstrœmella.	*Schizobolus.
*Craniella.	*Linnarssonia.	*Schizocrania.
Craniscus.	Mesotreta.	Siphonotreta.
*Discina.	*Œhlertella.	*Trematis.
*Discinisca.		

Protremata.

(πρώ, early, and τρῆμα, perforation.)

Plate xvii, figures 13–21.

Protegulum of the brachial valve as in the Atremata. In the pedicle valve, it has become modified through acceleration to an elliptical or circular form with arcuate hinge. Pedicle enclosed in early nepionic stages by shell growth; posterior covering (pseudo-deltidium) retained at maturity, or resorbed or abraded in nealogic stages, so that the pedicle protrudes between the two valves. The stages of growth, in general, represent (1) a paterina stage, with straight hinge line and pedicle opening shared by both valves; (2) a discinoid stage, without straight hinge, pedicle enclosed by concentric peripheral growth of pedicle valve; and (3) a straight hinged condition, with pedicle opening either retained or merged into fissure of hinge area. Valves articulate.

Including the genera:—

Amphigenia.
Aulosteges.
Bactrynium.
Bilobites.
Camarella (group).
Camarophoria.
*Chonetes.
Clitambonites.
Conchidium.
Davidsonella.
Davidsonia.
Daviesiella.
Derbya.
Enteletes.
Eudesella.
Hemipronites.
Hipparionyx.
*Lacazella.
*Leptæna.
Leptænisca.
Lyttonia.
Meekella.
Mimulus.
Oldhamina.
*Orthis (group).
Orthisina.
*Orthotetes.
Pentamerella.
Platystrophia.
*Plectambonites.
Porambonites?
Proboscidella.
*Productella.
Productus.
*Rhipidomella.
Schizophoria.
Sieberella.
Streptis.
*Streptorhynchus.
Stricklandinia.
Strophalosia.
*Stropheodonta.
*Strophomena.
*Strophonella.
Thecidella.
*Thecidium.
Thecidopsis.
Triplecia.
*Tropidoleptus.

Telotremata.

(τέλος, last, and τρῆμα, perforation.)

Plate xvii, figures 22–28.

Protegulum as in Atremata. Pedicle opening shared by both valves in nepionic stages, usually confined to one valve in later stages, and becoming more or less limited by two deltidial plates in ephebolic stages. Arms supported by calcareous crura, spirals, or loops. Valves articulate.

Including the genera:—

Acanthothyris.	Hindella.	Platydia.
Ambocœlia.	Ismenia.	Rensselæria.
Amphiclina.	Karpinskya.	Reticularia.
*Athyris.	Kayseria.	Retzia.
*Atretia (Cryptopora).	Kingena.	*Rhynchonella.
*Atrypa.	Koninckella.	Rhynchonellina.
Bifida.	*Koninckina.	Rhynchoporina.
Bouchardia.	*Kraussina.	Rhynchotrema.
Centronella.	*Laqueus.	*Rhynchotreta.
*Cistella.	Leptocœlia.	*Spirifer.
Clorinda.	Liorhynchus.	Spiriferina.
*Cœlospira.	*Liothyrina.	Spirigerella.
Cœnothyris.	*Macandrevia.	Stringocephalus.
Cryptonella.	Magas.	Suessia.
Cyrtia.	*Magellania.	Syringothyris.
Cyrtina.	*Martinia.	*Terebratella.
Dayia.	Martinopsis.	Terebratula.
Dictyothyris.	Megathyris.	*Terebratulina.
Dielasma.	Megalanteris.	Terebratuloidea.
Dimerella.	*Megerlina.	Thecospira.
Disculina.	Merista.	Trematospira.
Eatonia.	*Meristella.	Trigonosemus.
Eudesia.	*Meristina.	Uncinulus.
Eumetria.	*Muhlfeldtia.	Uncites.
Glassia.	Nucleospira.	Zellania.
Grunewaldtia.	Pentagonia.	*Zygospira.
*Hemithyris.	Peregrinella.	

Yale Museum, New Haven, Conn., March, 21, 1891.

EXPLANATION OF PLATE XVII.

Atremata.

FIGURE 1.—Brachial valve of *Paterina labradorica*, Billings. ×3.
FIGURE 2.—Pedicle valve of young specimen. ×3.
Primordial. *Near Georgia, Vermont.*
FIGURE 3.—Apex of pedicle valve of *Glottidia Audebarti*, Brod. ×25.
FIGURE 4.—The same; brachial valve; showing more distinctly terminal protegulum. ×25. Recent. *Beaufort, North Carolina.*

Neotremata.

FIGURE 5.—Upper valve of nepionic *Orbiculoidea minuta*, Hall; representing protegulum (*p*) and paterina stage. ×25.
FIGURE 6.—More advanced condition; showing acquisition of discinoid characters. ×25.
FIGURE 7.—Lower valve of young specimen; showing protegulum and open pedicle notch. ×25.
Devonian, Marcellus Shale. *Avon, New York.*
FIGURE 8.—Accelerated. discinoid, dorsal protegulum of *Discinisca lœvis*, Sowerby, corresponding to nealogic stage of *Orbiculoidea minuta*, figure 6. ×25.

FIGURE 9.—Ventral protegulum of same species similarly modified, agreeing with figure 7. × 25.

FIGURE 10.—Lower valve of same species; showing submarginal position of pedicle opening. Natural size. Recent. *Callao, Peru.*

FIGURE 11.—Lower valve of *Schizotreta tenuilamellata*, Hall; showing centripetal tendency of pedicle opening. Natural size.
Niagara Group. *Hamilton, Ontario.*
(Pal. N. Y. Extract from vol. viii, pl. IVE, fig. 10, 1890.)

FIGURE 12.—Lower valve of *Acrothele subsidua* (after Linnarsson); showing subcentral position of pedicle opening. Natural size.

Protremata.

FIGURE 13.—Dorsal protegulum and early nepionic growth lines of *Plectambonites segmentina*, Angelin. × 80. Upper Silurian. *Gothland, Sweden.*

FIGURE 14.—Dorsal protegulum of *Chonetes scitulus*, Hall. × 80.
Hamilton Group. *Thedford, Ontario.*

FIGURE 15.—Accelerated discinoid ventral protegulum of *Chonetes granuliferus*, Owen; showing pedicle notch. × 80.
Coal Measures. *Manhattan, Kansas.*

FIGURE 16.—Discinoid nepionic stages of ventral valve of *Orthotetes elegans*, Bouch. × 25. Compare with figure 12 of Acrothele.
Devonian. *Ferques, France.*

FIGURE 17.—Nepionic stages of *Stropheodonta perplana*, Conrad; showing pedicle perforation, pseudo-deltidium, and hinge area. × 25.
Hamilton Group. *Falls of the Ohio.*

FIGURE 18.—Ventral nepionic discinoid stage of *Strophomena rhomboidalis*, Wilck. × 25.

FIGURE 19.—Profile of the same. × 25.
Lower Helderberg Group. *Albany County, New York.*

FIGURE 20.—Hinge of a specimen 2^{mm} in length; showing deltidial covering and hinge area.

FIGURE 21.—Ventral view of specimen having same dimensions; showing nepionic and nealogic stages, and relative proportions of pedicle opening and shell at this stage. Niagara Group. *Waldron, Indiana.*
Figures 20 and 21 are taken from "Development of Some Silurian Brachiopoda," Mem. N. Y. State Museum, vol. i, No. 1, pl. II, figs. 2, 12, 1889.

Telotremata.

FIGURE 22.—Ventral view of young *Kraussina* (*Megerlina*) *Lamarckiana*, Davidson; showing protegulum and early nepionic stages. × 80.

FIGURE 23.—Dorsal view of same; showing dorsal protegulum and pedicle opening in ventral valve. × 80. Recent. *Port Jackson, Australia.*

FIGURE 24.—Dorsal view of beaks of young *Terebratulina septentrionalis*, Couthouy; showing dorsal protegulum and pedicle opening in ventral valve. × 80. Recent. *Eastport, Maine.*

FIGURES 25–28.—Diagrammatic representation of ventral areas; showing progressive development of deltidial plates. Figure 25 is without plates, as in ventral area of figure 23. Figure 26 shows two triangular plates, which unite by symphysis in figure 27, making an elongate pedicle opening. In figure 28, pedicle perforation is subcircular and truncates ventral beak. This series corresponds essentially with that shown in *Rhynchotreta cuneata*, Dal., in "Development of Some Silurian Brachiopoda," loc. cit., pl. IV, figs. 16–22.

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ART. XLI.—*On the Relationship of the Pleistocene to the Pre-pleistocene formations of the Mississippi Basin, south of the limit of glaciation;** by T. C. CHAMBERLIN and R. D. SALISBURY.

THE deposits made by the ice and by the waters which originated from it during the glacial period, possess a character so unique, and so markedly unlike that of the underlying formations within the glaciated area of the United States, that there has been little difficulty in discriminating between them. There have been differences of opinion as to the relative importance of the various agencies which are believed to have been operative in the production of the drift, and in some minor measure these differences still exist. But whether the drift of any particular region be believed to be the work of glaciers, or of icebergs or ice-floes, or of glacionatant lakes or streams, or the joint work of two or more of these agencies, still the drift, as such, is clearly defined from the underlying strata. In many regions, this is true no less of the valley drift which stretches beyond the glaciated area along the avenues of discharge for the melting ice, than of the unmodified drift upon the extra-valley lands farther to the north, where the drift agent is believed to have been land ice.

* The writers have worked in such close association in the study of this and of correlated regions, that it is difficult to define their individual work and their respective responsibilities; nor is it important; but they have reasons for stating that the preliminary determination of the salient features of the correlation, and the direction of the investigation, are largely the work of Mr. Chamberlin, while the detailed investigation, the elaboration of results, and the preparation of this article are chiefly the work of Mr. Salisbury.

But in the central part of the basin of the Mississippi River below the latitude of glaciation, the difference between the deposits made by the waters originating in the melting ice, and the subjacent strata, appears to be much less obvious than in many other regions. In consequence, the recognition of the Pleistocene formations along the course of the Mississippi south of the limit of the general drift sheet, and therefore the correlation of the northern and southern Pleistocene formations, has not been free from difficulties.

The Loess.—The highlands bordering the Mississippi Valley on either side, between the parallels of 37° 30′ (the southern limit of glacial drift), and 35° are overspread by loess. The loess extends much below this latitude, but that is the lower limit of the area especially under consideration. A belt of loess similarly disposed occurs along the course of the Ohio, for a considerable distance above its junction with the Mississippi, though the loess along this stream is less constant in character, and its facies often different from that of the Mississippi River loess. Consonant with the general habit of this formation, the loess is best developed on the highlands immediately adjacent to the rivers. In such situations, the loess possesses the loose, open texture which is one of its most diagnostic characteristics. As the formation is traced eastward or westward from the Mississippi, or northward or southward from the Ohio, these characteristics gradually disappear. The open texture becomes less pronounced, and by almost imperceptible degrees passes from that of a loose, light loam, through that of a clayey loam, to that of a loamy clay. So far does this gradation proceed, that the texture of the loam at some distance from the streams, resembles much more closely that of the residuary earth upon which it rests, than that of the typical loess, on the immediate borders of the valley.

A change in color accompanies the change in texture. The buffish color which everywhere characterizes the river bluff loess in its normal development, becomes deeper with increasing distance from the streams, so that along the borders of the loess, where the texture has come to simulate closely that of the residuary earths, the color has become notably deeper than on the bluffs immediately fronting the river, and the deepening color has been a constant approximation to the color of the underlying residuary earth.

Accompanying the change in texture and color, are changes in the chemical character of the loess. Near the rivers it almost uniformly contains a considerable percentage of carbonates. Here too, it very generally contains shells, and concretions of calcium carbonate, the one a partial cause, and the other at once an index and a result of its calcareous character.

The shells, the concretions (*loess-kindchen*), and the calcareous nature of the loess, are features not less characteristic, though less universal, than the texture itself. As the texture of the loess becomes closer and its color deeper with increasing distance from the rivers, the proportion of carbonates diminishes, and may entirely disappear before the border of the loess is reached. The shells and concretions are limited to the calcareous portions of the loess, or they may be still more restricted in their distribution.

With increasing distance from the streams goes another change in the composition of the loess. The complex silicates (feldspar, mica, hornblende, augite, etc.), which are found to be very significant ingredients of the formation along the river bluffs, become less and less abundant, as the other normal characteristics disappear. They may be found, however, in the loams remote from the streams, after almost every other true loess feature has disappeared.

The thickness of the loess diminishes regularly with increasing distance from the rivers. So far does this thinning proceed, that at a distance of a few miles from the streams, but a thin mantle remains.

The features thus indicated as pertaining to, and defining the loess in the region under consideration, are the features which characterize it throughout its distribution to the north along the Mississippi, and along its tributaries in Illinois, Missouri, Iowa, Wisconsin and Minnesota, and along the tributaries of the lower Ohio, in Illinois and Indiana.

Throughout much of this territory the loess lies upon the glacial drift. In southern Illinois, for example, the drift for many miles north of its southern boundary is overspread with loess, or with clay-like loam which may be traced into direct continuity with the normal, open-textured, calcareous, shell- and concretion-bearing loess, along the immediate valleys of the streams. Here too, in scores and hundreds of places, especially in southeastern Illinois, it may be seen that the surface of the drift upon which the loess rests, is one which gives no evidence of exposure to the atmosphere before the mantling loess was spread upon it. Had such exposure found place, the fact would have left its record in the oxidation of the exposed surface, or in the accumulation upon it of an old soil, traces of which would still be found beneath the loess. But in southeastern Illinois and the adjacent parts of Indiana, no zone of oxidation, and no vegetable layer, or trace of old soil, separates the loess from the till beneath. It would not be necessary to suppose that such a zone as that here referred to would necessarily be preserved at all points, until the present time. But its universal absence over large areas, under conditions which

must have been favorable for its preservation, had it ever been developed, seems to be conclusive against the hypothesis that it ever existed. That the conditions were favorable for its preservation is proved by *its well-nigh universal presence under the loess immediately south of the drift border, in the same region.*

In many places, it may be clearly seen that the superficial loess-mantle and the stony drift beneath, meet each other in a thin zone of gradation. That is, the pebbles of the drift frequently occur in the basal portion of the mantling loess, in and just above the horizon where the imbedding matrix changes from a gritty clay (till) to a gritless loam or loamy clay (loess). In other places, there is a more or less marked accumulation of drift pebbles* immediately below the loess or its clayey equivalent, marking its junction with the till. Both these relationships find ready explanation in the hypothesis that glacial waters covered the till, and spread the mantle of loess upon it immediately after the ice retreated. And no other hypothesis seems to meet the case. In the judgment of the writers, therefore, the relationship between these two deposits, the till and the loess, as seen in innumerable sections, in southeastern Illinois and southwestern Indiana, is such as to admit of no second interpretation as to their sequence. The loess, in the regions where such sections are found, was deposited immediately after the till, so far as not actually contemporaneous with it. We distinguish other sheets of loess, contemporaneous with other stages of glaciation, and some of these are separated from underlying till by old soils, but these do not require special consideration here. The active agent concerned in the production of the loess is believed to have been water, and the material of the loess was in part derived from the till beneath, and in part from the glacial silt carried southward from the melting ice to the north. The evidence that the loess is really a glacier-made silt, re-worked by water, has been elsewhere discussed.†

The age of the loess covering the drift along its southern border, would seem to be clearly fixed relative to the underlying till. The till of the region belongs to the first glacial epoch, as we have been accustomed to distinguish the glacial epochs,‡ and this loess belongs to the closing stages of the same epoch, after the ice had retreated somewhat, but while the region to the south of its edge was still overspread, in part at least, by waters originating from it.

The first glacial epoch embraces at least two episodes of glaciation, separated by an interval when the climate of the

* *Steinsohle* of the German geologists.

† Sixth Annual Report, U. S. G. S., page 278 et seq. ‡ Loc. cit., page 212.

southern part of the drift-covered area was so far ameliorated as to allow the growth of vegetation upon the drift of the first episode. In southeastern Illinois and the adjacent parts of Indiana, the ice advance of the second episode of the first epoch seems to have been equal to, if it did not exceed, that of the first episode. This seems not to have been the case in some portions of southwestern Illinois, but in southeastern Illinois, and indeed in most of the southern part of the state, the till immediately beneath the loess is referred to the second ice incursion of the first glacial epoch. The loess here under discussion is therefore to be referred to the close of the second glacial episode of the first glacial epoch. But it may be traced across the limit of the drift from north to south. The continuity is complete, and the character of the formation is the same on both sides of the line which marks the limit of ice advance. It is a continuous mantle, overspreading alike the drift border on the north, and the residuary earths which the ice did not disturb, on the south. If, therefore, the age of the loess which covers the drift be first glacial (first episode), the age of that which lies south of the drift, in the area under discussion, is likewise first glacial.

Between the relationship of the loess to the till north of the limit of glaciation, and the relationship of the loess to the residuary earths of the Paleozoic rocks immediately outside the drift, there is one important difference to which reference has already been made. The presence of a weathered and highly oxidized zone, immediately subjacent to the loess, south of the drift limit, is as conspicuous as is its absence to the north. This oxidized zone is the upper surface of the residuary earths. There is in places, a slight admixture of residuary material and loess at the junction of the two. But the body of the residuary earth is clearly separated from the body of the loess. The fact of the existence of a long interval between the loess and the residuary earths beneath, is as clearly indicated on the one hand, as is the fact of the absence of an interval between the loess and the underlying till on the other. The phenomena on each side of the drift limit, strengthen the conclusion drawn from the phenomena on the other.

There is in the nature of the case no manifest reason why the formation of loess should not have accompanied and followed the ice action of the first episode of the first glacial epoch, just as it accompanied and followed the second episode. Assuming this to have been the case, there should be a twofold division of the loess south of the drift, theoretical, if not observable. Such division has been sought for, but without completely satisfactory results, throughout most of the area under consideration. There are a few localities east of the

Mississippi river, as at Memphis, Tenn , where there is some evidence of the division here suggested. The evidence consists in the presence of a thin layer of humus-stained (apparently) loam, between beds of loess, suggesting an old soil. At Forrest City, Ark., there is a similar layer of dark loam, in similar relationships, while at numerous points farther north on Crowley's Ridge, both in Arkansas and Missouri, there is a thin zone of oxidized (red) loam, occupying a corresponding position. The great majority of sections, however, present the aspect of consecutive deposition; at least no positive signs of separate stages of deposition have been observed.*

The Gravels and Sands subjacent to the Loess. ("Orange Sands.").—Beneath the loess, in the southernmost counties of Illinois, in northern and northwestern Kentucky, in western Tennessee, in northeastern Arkansas, and southeastern Missouri, there is a remarkable series of gravels and sands. In portions, at least, of this area, the gravels and sands have been known in geologic literature under the name of Orange Sand. Unfortunately for clearness of understanding, this term has been differently used by different geologists. The Orange Sand or Lagrange formation of Tennessee (Safford), is regarded by Professor Safford as the partial equivalent of Professor Hilgard's Northern Lignitic, and is referred by both geologists to the Tertiary, Safford regarding it as Miocene, though expressing doubt whether it be not older, and Hilgard regarding it as Eocene.† The Bluff Gravels of Safford appear to be the Orange Sand of Hilgard, and are classed by both geologists as Quaternary. Within the area under consideration, both the Lagrange or Orange Sands of Safford, and the Bluff Gravels (Safford), or Orange Sands of Hilgard, occur, and both are covered by loess. With the classification of these formations, and with the question of the relations between the Lagrange Sands and the Bluff Gravels, this article does not deal. It has only to do with their pre-pleistocene age, and with the relation of the loess to them. The Bluff Gravels (Safford) occupy the surface (below the loess) of the river bluffs at various points in Tennessee, while the Lagrange Sands occupy the surface farther east. Farther north, however, sands and gravels which appear to be the equivalent of the Bluff Gravels of Tennessee, have a much greater thickness than in the latter state, and it is not altogether clear that they do not include beds below the Bluff Gravels of Safford. Be that as it may, the gravels have a much greater vertical range in Southern Illinois than has been observed by the writers further to the south. The Bluff Gravel formation "consists

* See further the foot note at the close of the article, p. 377.

† This Journal, vol. xli, page 370, 1864.

generally, of coarse yellow and orange sands, with everywhere more or less coarse gravel, and has usually a layer of white or variegated clay at the base. The gravel is . . . . sometimes cemented by oxyd of iron into great blocks of coarse conglomerate."* Setting aside the question as to subdivisions of the gravels and sands and clays, which the geologists of Illinois have seen no good reason for separating,† it is true, generally speaking, that the body of the gravel overlies the sand. More accurately, the gravel predominates above and the sand below, though the gravel is to be found more or less generally distributed through a considerable vertical range, in the formation in southern Illinois.

Within this series, there are often seams and pockets, or even considerable layers of kaolin-like clay, remarkable alike for its irregularity of development and its brightness and variety of coloring. Oftener than otherwise, the clay is in the lower part of the sand and gravel stratum, but many localities are known to the writers where heavy beds of gravel and sand occur below a considerable thickness of clay. In such cases at least, the clay would seem to be of necessity correlated with the sands and gravels.

At several horizons in various localities, the sand becomes more or less coherent from the presence of a fine sticky matrix of earthy material. The matrix may even predominate over the sand, giving rise to a gritty clay or loam, rather than to a sticky sand. Such gritty clays are wholly unlike the kaolin-like clays above noted. The latter are gritless and variegated in color. The clays here designated as gritty, have always a goodly proportion of coarse sand, and are either of a deep red or a brownish color. In these gritty clays there are frequent laminæ of sand, of variable thickness, and these laminæ are often cemented, forming layers of sandstone of considerable hardness. The same is frequently true of laminæ of sand, and even of layers of considerable thickness, within the body of the sand itself, where there is little admixture of earthy material. In all these cases iron oxide is the chief cement.

Induration is not confined to the sand. Not rarely portions of the gravel are cemented into a firm conglomerate, the cementing material being the same as in the case of the sand. More commonly than otherwise, it is the uppermost portion of the gravel which has been indurated, but there are so many exceptions that this can hardly be said to be the rule. The thickest beds of conglomerate which have been seen by the writers (near Metropolis, Ill.) occur at a low horizon, and (though not shown in vertical section) beneath considerable thicknesses of sand, clay, and loose gravel.

* Safford, this Journal, vol. xxxvii, page 371, 1864.
† Engelman, vol. i, Geol. Surv., iii, page 423.

It is a peculiarity of the distribution of loess, that elevations within the area of its occurrence seem to be no obstacle to its presence. The loess is quite as likely to find its normal development on the higher lands as on the lower. Within the area especially under consideration, the same may be said concerning the gravels. They exist on the highest hills, under the loess, and in fact, speaking generally, find there their best development. The gravels are frequently absent from the slopes of the hills, or but meagerly developed upon them, even when present in quantity upon their crests. These sands and gravels, or at least the portion of them known under the name of Orange Sand (Hilgard), have heretofore generally been regarded as Quaternary, and have even been referred to the Champlain epoch.*

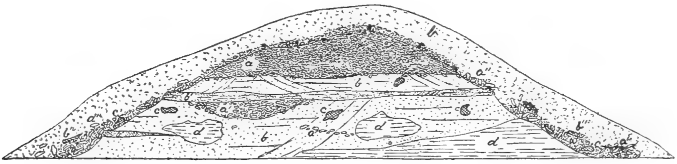
We have already seen, however, that the evidence is conclusive that the loess is to be referred to the melting waters of the first glacial epoch, and the Orange Sand, so far from being referred to a time subsequent to the second glacial epoch, must be referred to a time earlier than the closing stages of the first glacial. How much earlier?

It would not be irrational to suppose that the waters of the melting ice might carry down, along the courses which they followed, great quantities of detritus. Gravel and sand might thus be distributed wherever the currents were strong enough to carry them, conceivably for great distances south of the limit of ice advance, just as gravels are carried far beyond the ends of glaciers to-day by the streams issuing from them. The Mississippi valley must have been an avenue for the discharge of glacio-natant waters, and it would not be strange were glacial gravels found in the same, beyond the extra-valley drift limit, just as glacial gravels, originating from the ice of the second epoch, are found down the valleys far beyond the limit of ice advance at that time. Were the Orange sands and gravels formed in the manner above indicated, and at the time which this origin would necessitate, viz: in the first glacial epoch, we might find evidence of the fact along three several lines, any one of which would be conclusive.

If the gravels be referable to the time of glaciation immediately preceding the deposit of the loess, we should find the loess spread over these gravels conformably, or with only such slight unconformity as might have been developed locally in the interval between the deposition of the gravels, when the

* Hilgard: Agriculture and Geology of Mississippi, 1860. Also this Journal, vol. xli, page 311, 1866. Safford: *Ibid*, vol. xxvii, page 361, 1864. Dana: Manual of Geology, 3d edition, page 548. LeConte's Elements of Geology, page 540. Loughridge: Kentucky Geol. Surv. Jackson Purchase Region, 1888, page 57 *et seq*. By the Geological Survey of Illinois, the formation in question has been regarded as Tertiary. Vol i, page 417, *et seq*., and page 447, *et seq*.

streams must have been active, and the deposition of the loess, when the streams must have been sluggish. In point of fact such conformity, or so much of conformity as this hypothesis would demand, does not exist. The following diagrammatic section shows the relationship which may be seen to exist between the loess and the gravels and sands, at numerous points in southern Illinois.



Loess (*l*) covers the whole hill. Beneath it, the hill is capped with gravel (*a*). This constitutes a well developed layer, several feet in thickness. The pebbles composing this layer almost uniformly lie upon their surfaces of greatest diameter, and appear to be closely packed. The gravel may be cemented or not. On the slopes of the hill below the gravel layer, there are pebbles (*a″*) few or many, identical in character with those above. Unlike the gravel layer above however, these pebbles have no particular arrangement, and have the appearance of having rolled down the slope to their present position. Along with the loose pebbles there may be masses of conglomerate originating from the gravel above, in case the same is cemented. Beneath the gravel, there is a considerable body of sand (*b*), sometimes distinctly stratified and sometimes not. Seams or pockets of gravel (*a′*) identical in character with that above, may occur in the sand, and occasional pebbles exist where no well defined seam can be traced. Laminæ of the sand at frequent intervals are indurated (*b′*), and bits of ferruginous sandstone derived therefrom, (*b″*) are freely mingled with the pebbles which have come down from higher levels. The pebbles and the sandstone fragments lie upon the eroded edges of the nearly horizontal layers of the sand and gravel stratum. Together with these talus materials there are often large numbers of iron-cemented sand-concretions (*c′*), identical in kind with those (*c*) which may be taken from the undisturbed beds of sand. Like the fragments of the sandstone, they originated close at hand, in the sand layers of the hill itself.

The erosion slopes of the hills, cut out of the horizontally though irregularly stratified sands and gravels, are thus seen to be strewn with gravel, sandstone debris, and ferruginous concretions, originating from the same series higher on the slope. Overspreading the whole, covering the crests of the

hills and the eroded edges of the sand and gravel layers, together with their thin covering of local debris, as above indicated, is the mantle of loess. It is absent only where recent erosion has been sufficient to effect its removal. How far the uniformity of distribution of loess over regions of strongly accentuated relief may be due to the creep of the plastic material down the slopes, is not here discussed; but this is not believed to be an adequate explanation of its uniform slope distribution. The loess and its clayey equivalents, are confidently believed to have been deposited like a mantle over a previously eroded surface. If the body of the hills be Paleozoic rock with only a capping of gravel and sand, the relation of the loess to the latter is not altered.

In view of this marked unconformity, it seems necessary to conclude that the deposition of the gravels and sands must have antedated a long period of pre-loessial erosion, since they themselves suffered erosion, and very extensive erosion, before the close of the first glacial epoch, when the main body of the loess appears to have been deposited. In many places there is evidence that cementation of the gravels and sands of the Orange Sand formation, had been accomplished before erosion had proceeded far. But since cementation may proceed rapidly, it does not seem necessary to allow for any notable interval of time, succeeding the deposition and preceding the erosion of the sands and gravel. Such interval must have been long enough, however, to allow for the shifting of attitude necessary to change the area of Orange Sand, from one of subaqueous deposition, to one of subaërial erosion.

The force of the above argument is not destroyed, although it may seem to be weakened, by the fact that the relationship between loess and Orange Sand here depicted, does not hold throughout the whole area of the development of the latter. Nowhere else, within the range of the writers' observation, is the unconformity so well shown as in southeastern Illinois. But similar facts are less strikingly exhibited at various points in southeastern Missouri, in western Kentucky, in Arkansas and Tennessee. That the degree of unconformity should vary is not strange, since the attitude of the land was such as to expose it to greater erosion on the flanks of the valley and the highlands of southern Illinois, than in the axis of the valley, where the approach to conformity is greatest. In the south the land appears to have remained so low as to allow of little or no erosion beween the Orange Sand and the loess.

From a second line of evidence it may be safely concluded that there was an interval of considerable duration between the deposition of the loess and the deposition and exposure of its substratum.

Although the lapse of time since the closing stages of the first glacial epoch is great, the loess does not appear to have undergone any considerable alteration in chemical character since the time of its deposition. Its surface portion for a depth of 4–6 feet, often shows unmistakable signs of oxidation and weathering. Locally, oxidation has penetrated to greater depths. The particles of the surface portion have been disintegrated by chemical and physical means, so that they have become notably finer than they were at the time of their deposition, and finer than those of the lower portions at the same locality. Were another sheet of loess to be spread over the first to-day, the distinction between the two in later times would be perfectly clear, on account of the chemical and physical changes which the present loess has suffered in its superficial parts. Yet even this distinction would be far less conspicuous than that which now exists between the loess and the surface of the underlying material. This comparison may be in some sense unfair, since it is true that the substratum of the loess and the loess itself are inherently dissimilar; but it is not that difference which is here insisted upon. It is the degree of alteration which the surface of the material below the loess has suffered—an alteration such as surface exposure would effect—which is of significance, and this alteration, which must have taken place before the deposition of the loess, is in general very much greater than that which the surface of the loess has undergone since the close of the first glacial epoch.

In many places there is a thin layer (4–8 feet) of earth above the gravels of the Orange Sand series. This is believed to represent, in many places at least, the last work of the waters which deposited the coarser materials below. It is commonly somewhat gritty, the gritty element (sand) partaking of the nature of the sand below, but it is distinctly clayey in texture. The textural difference between it and the loess is much less than that between the loess and the upper surface of the Orange Sands as commonly developed, but quite as great as that between the loess and the till. But it is in just such situations that the line marking the junction of the loess and the underlying earth is most conspicuous and significant. The latter shows the texture and deep coloration which denote the oxidation and surface alteration that result from long exposure to atmospheric action. In many places the junction of the loess with this layer, is the most obtrusive line in the section. In more than one place, it may be noted in passing, does this super-gravel earth show an eroded surface, upon which the loess rests unconformably, though the degree of unconformity in such cases is often slight.

The chemical changes in the sands and gravels are not confined to their surfaces. Beneath the surface, and so far beneath as to be below the zone of active surface weathering, there is evidence that great changes have taken place, denoting the lapse of long intervals of time. The most obvious of these changes is the extent to which the leaching and concentration of coloring matter has been carried. Besides this there are various other changes less clearly defined, but which in the aggregate give to the whole series below the loess an appearance of age which is unmistakable. The changes which the Orange Sands have undergone since their deposition, certainly appear to be several times as great as those which the loess has suffered since its deposition. And while this might not be a safe standard for chronological measurements, taken by itself, it has a strong corroborative significance, since it falls into correspondence with conclusions drawn from other lines of evidence.

Outside the drift region, the material underlying the loess is often residuary earth derived from Paleozoic rock, instead of from Orange Sand. So far as oxidation and the changes induced by exposure are concerned, the residuary earths of the Paleozoic rocks do not seem notably more affected than those of the Orange Sands. This is but an eye estimate, and may be erroneous quantitatively considered, though it is based on the observation of hundreds and thousands of sections. But in any case the fact of very profound affection of the pre-loessial surface by atmospheric agencies in pre-loessial times, is believed to be beyond dispute. And this is no isolated phenomenon. Generally speaking, it holds throughout the length and breadth of the extra-drift loess territory, within the limits of the writers' observation, and by report much beyond. On this point Professor Hilgard writes:* "The Orange Sand . . . . . as a rule contains nothing that is capable of further oxidation or solution by atmospheric agencies, unless it be silex. Such complete peroxidation and lixiviation, the effects of which have been largely extended into underlying formations, unquestionably indicates a long subaërial exposure, from which the northwestern stratified drift was in a great measure exempt." Dr. Loughridge† likewise recognizes the presence of "a bed more clayey and darker (than the loess) in color," between the loess and Orange Sand at Hickman, Ky., and "4 feet of the stiff darker loam" below the loess and above the gravel at Columbus, Kentucky. These "darker loams" represent the oxidized and

* This Journal, vol. iv, page 266, 1872. The same point is repeatedly insisted upon by Professor Hilgard in other articles in this Journal, and in his report on the Agriculture and Geology of Mississippi.

† Kentucky Geol. Surv., Jackson Purchase Region, F., 1888, page 78.

humus-stained material of the pre-loessial surface, as we interpret the phenomena, and are to be sharply discriminated from the loess, with which, except in the matter of position, they have nothing to do We fully concur with Professor Hilgard in his conclusion that this material "unquestionably indicates a long subaërial exposure," before the deposition of the loess. In a few localities where the pre-loessial surface does not appear to have suffered erosion, and where the loess therefore appears to be conformable with the substratum, the junction is marked by a humus-stained layer indicating an old soil. This occupies the same position, relatively, as the oxidized and weathered upper surface of the Orange Sands described above, and points to the same conclusion as to the sequence of events.

From the relative position of loess and Orange Sand, it is evident that the latter is the older. From the stratigraphic relations of the two formations, it is equally evident that the deposition of the former followed that of the latter, only after a considerable interval of time. The chemical changes which the older formation has suffered, strengthen the conclusion drawn from the unconformity, that the interval was long.

The main deposition of the loess seems to have taken place during the second episode of the first glacial epoch. The only evidence that we have thus far developed of a similar deposition that could be referred to the earlier episode of the first glacial epoch, is found in the lower stratum of loess, separated from the higher by the humus-marked and oxidized horizon, referred to above, as occurring at Memphis, Forrest City, and several other points on Crowley's Ridge. This lower subdivision of the loess, although fairly differentiated at these points, is not distinguishable at a sufficient number of points to make it certain that it is the fluvial representative of the first episode of the first glacial epoch.* If the force of the correlation of this lower division of the loess with the earliest drift be set aside, it might be supposed that the Orange Sands were synchronous with the first episode of this epoch. Were this their age, there would have been an interval between their deposition and the deposition of the loess. While this interval is not believed to have been long enough, or nearly long enough, to bring about the changes which the Orange Sand suffered before the loess epoch, our means of estimating time may be supposed to have led to erroneous conclusions, we therefore may seek the answer to the present question along another line.

* The observations recorded in the footnote on page 377, seem to make it reasonably certain that the lower subdivision of the loess here referred to, is the fluvial representative of the first episode of the first glacial epoch. This however does not weaken the argument here adduced, although it may seem to make it unnecessary.

Were the gravels and sands of the Orange Sand series to be referred to the first episode of the first glacial epoch, their origin should be revealed by their constitution, if glacial waters were the depositing agent. In this case we should confidently expect to find pebbles of northern origin among these gravels. It would not be necessary to suppose that all the gravel deposited by a stream springing from the glacier would necessarily be northern, since tributaries might bring in material from other directions, in the ordinary process of river degradation. But emphasize the importance of this latter consideration as we may, it yet remains an indisputable fact, that, were the conditions of drainage such that tributaries could bring gravel to their main in great quantities, the main itself, if springing from the ice, would inevitably bring something of glacial debris, which would be found mixed with the material of more local origin, brought in by the tributaries. And this would be true, even if the accumulation took place at an earlier stage of the glaciation of the first episode, long before the ice approached the latitudes under consideration; for the drainage basin of the Mississippi reaches several hundred miles to the northward, and probably extended still farther in that direction at an early stage of the ice invasion, when the ice had so far spread itself over the British possessions as to prevent drainage into Hudson's Bay.

If then, the Orange sands and gravels were accumulated during the first glaciation of the first glacial epoch, as valley or estuary deposits, we should of necessity have northern material represented in this formation, if not in the form of sands and gravels, *at least in the form of silt.* Such, however, is not the fact. In the hundreds of exposures of gravel which the writers have seen, large numbers of which, in various localities in six states, have been examined in detail for this especial purpose, not a single pebble of demonstrably northern or glacial origin has ever been found. Northern pebbles have been found associated with pebbles *derived from the gravels* under consideration, but only in such situations that the secondary character of the deposits containing such pebbles, was certain or altogether probable, from considerations entirely independent of those here adduced. And the freedom from glacial gravel and sand and silt does not characterize the Orange sands simply in their most southern distribution, where the local material might naturally be more abundant than to the north, but even up to the northern limit of the Orange Sand region, scarcely more than a score of miles from the southern border of the glacial drift, the northern or glacial materials are likewise altogether absent.

Even in the silts and loams that overlie the gravels and underlie the weathered and humus-marked horizon which divides the gravels, sands and silts below, from the loess above, microscopic examination fails to reveal the particles of the various complex silicates and dolomite which characterize the loess above, and which characterize all glacial silts with which we have any familiarity. It is to us wholly incredible that these sands and silts could have been deposited by a river originating in a glaciated tract, without including these characteristic products of the glacial grinding.

If it be suggested that the gravels date from the interval between the two glaciations of the first glacial epoch, and so from a time when the streams did not carry glacial waters, the case is no better. For on this hypothesis, even if the main stream did not carry glacial waters at the time of the deposition of the sands and gravels, it was still coursing through a basin covered with drift, and this drift must certainly have yielded its contributions to the river gravels, for by hypothesis the conditions of drainage were such as to allow the rivers to transport gravel and sand. The only escape from this conclusion would be to suppose that neither the Mississippi nor its tributaries north of the limit of drift, had power to transport sand and gravel, or even silt, and that both the Mississippi and its tributaries south of the drift limits, had such power. But it is incredible that there could have been drainage conditions up to within 25 miles of the edge of the ice, or up to within 25 miles of the drift sheet if the ice had retreated, such that enormous quantities of gravel could have been brought in by tributaries from right and left, and carried down by the Mississippi well toward the Gulf of Mexico, while the Mississippi just above the point where current velocities necessary to the above work existed, should be so sluggish as to bring down nothing whatever of glacial gravel or sand or silt from the north. If the main were strong enough to carry down the gravel of its extra drift tributaries (and it certainly was, if the Orange gravel be river gravel at all, or if it ever were transported through the Mississippi valley), it would in all likelihood be strong enough to erode above these tributaries, and the material which it brought down from its intra-drift course, would be admixed when deposited, with that contributed by the extra-drift tributaries. If then the Orange gravels be river gravels, and if drift existed in the Mississippi basin when they were deposited, even if the ice had wholly retreated from the same so that no glacial waters coursed through the valley, such drift must certainly have yielded a contribution of gravel and sand to the Mississippi, both directly and through tributaries, at the same time that the tributaries south of the drift

limit were making their contribution of sand and gravel. In this case as in the other, there would necessarily be northern material in the gravel. The freedom of the Orange sands from all northern material, therefore, seems altogether conclu sive against the reference of its gravels to the time of the first glaciation, or to any time subsequent to the first glaciation.

We are not oblivious of statements concerning the constitution of the Orange sand and gravel, which are quite at variance with our own. By implication at least, all geologists who have referred them to the Champlain epoch, assign them a northern origin. Professor Hilgard thinks the difference between the Orange sand formation and the northern drift, "quantitative rather than qualitative," and that the materials of the two "are essentially correspondent,"* but we have been unable to find any basis in the regions we have studied, for such conclusions.

If the position of the Orange sands under first-glacial loess be fatal to their reference to the Champlain epoch, and if their unconformity with the loess, and their "perfect peroxidation" antecedent to the deposition of the loess, be fatal to their reference to an epoch immediately preceding that of the loess, no less does the complete absence of glacial material from the Orange sands and gravels, seem to us to preclude their reference to the ice period, or to any period subsequent to the first ice invasion. We are therefore shut up to the conclusion that the Orange sands are Pre-pleistocene. And even if an occasional northern Archæan pebble should hereafter be found in the Orange sand, we should not, on the strength of this evidence alone, regard our present conclusion invalidated; for the drainage basin of the Mississippi reaches well back into the area of Archæan rocks, and it would not be at all surprising if Archæan pebbles from this source should have found their way into the lower Mississippi Valley before the glacial period.†

It may be an open question whether the formation below the loess in the region under consideration, immediately preceded the Pleistocene, but it is not the purpose of this article to discuss that question. It is pertinent to the subject here discussed, however, to remark that the conditions of drainage during the first glacial epoch were such as to produce only exceedingly sluggish currents, so far as now known. But the Orange sands, whether of fluvial or estuarian deposition, date

* This Journal, vol. xli, pp. 313 and 315, 1866.

† Hilgard says (this Journal, xli, p. 318), that there have been found "rare and well worn pebbles of greenstone, porphyry, trappean rock, and even mica schist, ... among the shingle of the Mississippi band," and raises the question whether they may not have originated from Arkansas. Considering the absence of such material in the gravels of the Orange sand formation farther north, this hypothesis seems plausible.

from a time when drainage conditions were such as to allow the rivers to bring in large quantities of gravel, and often of very coarse gravel, from widely different sources. It is therefore manifest that the attitude of the country must have been very different in the Orange Sand and the glacial epochs, and the shifting of attitudes to match the drainage conditions of these two epochs, may have involved a considerable lapse of time.

In the light of the foregoing evidence, we find but one conclusion possible, respecting the age of the Orange Sand. In six states at least, it is true that beneath the loess and above the Orange Sand there is an old surface so deeply weathered and oxidized, as to indicate a long period of exposure before the deposition of the loess. Occasionally this old surface is humus-stained, indicating the growth of vegetation upon it, before the subsequent formation was made. Between this weathered and oxidized or humus-stained surface and the loess, there is wide-spread and often striking stratigraphic unconformity. Everywhere below this horizon, which is clearly recognizable in nearly every one of the thousands of exposures seen by the writers, there is an absence of material which can be referred to a glacial origin, while above this horizon, the loess and other fluvial deposits contain material of glacial derivation.* *This old surface, this horizon of oxidation, weathering and erosion; this horizon below which glacially derived materials do not occur, and above which they are present, we hold to be the dividing plane between the Pleistocene and the Pre-pleistocene formations.*

Thus far no mention has been made of certain beds of gravel which have given rise to more or less of misinterpretation. So soon as the gravels of the Orange Sand series were elevated above the waters which deposited them, their degradation began. From these Pre-pleistocene gravels, materials have been eroded and re-deposited throughout the course of Pleistocene time, and these processes of erosion and re-deposition are still in progress. That there are, therefore, beds of gravel derived from the Pre-pleistocene formation in Pleistocene times, goes with saying. Such of these beds as were formed in Pleistocene time previous to the deposition of the loess, might well contain glacial pebbles. Such of these beds as were formed during the epoch of the loess, and in the region where the loess was accumulating, necessarily contain something of the later material. In post-loessial times, too,

* Microscopic study of these silts and earths cannot be said to have been carried to an exhaustive extent. But the statements here made seem to be fully warranted by the work already done.

loess and gravel have been carried down slopes and deposited together at their bases. But none of the gravel beds of this category belong to the Orange Sand formation, or to the formation of bluff gravels of Safford, and their existence has no bearing upon the conclusion cited above.

It remains to indicate briefly the relationship of the second glacial deposits to those of the first, in the region under consideration. Starting from the points where the edge of the ice sheet crossed them, trains of gravels stretch down the valleys which served as avenues of discharge for the glacial waters. From the terminal moraines of the second epoch in which they head, these gravel trains, in the form of valley plains, extend down the valleys for great distances. Into these plains, post-glacial streams have sunk themselves, and such portions of the plains as have escaped removal constitute the gravel terraces which are so generally found in the valleys heading within the area of second glacial drift, from the Atlantic to Dakota. From the position of these terraces in relation to the terminal moraines, there can be no doubt as to their second glacial age. Their constitution too, in comparison with that of the material of the same grade of coarseness in the adjacent second glacial till, confirms the conclusion to which their position leads. Traced down stream, these terraces decline, somewhat rapidly at first, but soon more slowly. There is also a change in their physical constitution as followed down the valleys. The coarse gravel issuing from the moraines soon gives place to finer, and this ultimately to sand. Often there is but a single terrace, representing the level of the glacial flood plain, but often also, there are terraces at lower levels, representing subsequent stages of post-glacial river degradation.

These terraces of the Mississippi Valley are of especial significance in this connection, since this valley traverses the region under consideration. Not only does the altitude of the main terrace above the sea decline southward from the moraine, but its elevation above the stream likewise diminishes in the same direction, until it disappears altogether below the present flood plain of the Mississippi.* We have not seen the terrace south of the limit of glacial drift in Illinois, though terrace remnants near the mouths of tributaries occur at about that latitude, and may exist still further down the valley.

In the Ohio Valley at Louisville, there is a corresponding terrace, built up of material brought down by tributary streams heading within the area covered by second glacial ice. This

* Below the point where second glacial terraces have been identified, there are, in places, low plains slightly above the present flood plain of the Mississippi, which possibly are to be correlated with these terraces.

terrace, if we correlate rightly, may be traced nearly to the junction of this valley with that of the Mississippi. The streams tributary to the Ohio from the north, have their systems of terraces corresponding to those of their main, and the streams tributary to the Mississippi—so far as they head within the area of second glacial drift—are likewise terrace-bordered. At various points in many of these valleys, the terraces have been removed by late erosion, so that the modern flood plain extends from bluff to bluff.

The Mississippi Valley south of the latitude where the terraces occur, is known to have a filling of considerable depth and of geologically recent age. This filling, as we interpret, is in large part of second glacial origin, is in fact the southward extension of the northern terraces, and constitutes the only southern representative of the second glacial epoch. We have never seen the material brought up by the borings in the Mississippi flat, but borings in the Ohio flat, not far from the Mississippi (Mound City, Ill.), show sand of unmistakably glacial origin. Here the filling is certainly second glacial. The inference that the corresponding filling of the Mississippi is of the same age, lies close at hand, quite apart from the argument drawn from the southward decline of the Mississippi terraces, and their disappearance beneath the flood plain.*

* Since this article was written, the junior author has revisited some of the localities referred to in the first paragraph of p. 364, and at a season especially favorable for observations bearing on the question here raised. The lack of homogeneity in the loess is much more conspicuously shown when the face of the section is wet, than when it is dry, and it was mostly in the latter condition that the loess sections of this region had been seen heretofore. The new observations seem to leave little doubt that the loess, outside the drift limit, is to be referred to two episodes of deposition. The loess sections just east of Forrest City, Ark., seem most conclusive. Here there are two loesses, separated by a thin belt of humus-stained soil. This soil constitutes a sharply marked horizon throughout considerable parts of the extensive railway cuts near the station. It is not everywhere equally conspicuous, apparently containing varying amounts of organic material; but well-defined or ill-defined, it is a very persistent feature of the Forrest City cuts. The loams above and below this soil are identified as loess by their mineralogical constitution, by their fossils and by their *kindchen*. The upper surface of the lower loess sometimes shows unmistakable signs of oxidation and weathering, just below the soil. Laboratory tests for organic matter sustain the determination made in the field, that the coloring matter of the old soil is of vegetable origin. At scores of points in Illinois, Kentucky, Tennessee, Arkansas and Missouri, a similar division of the loess occurs, as distinctly marked as in some parts of the Forrest City section, where the less clearly marked soil is traceable into direct continuity with that which is unmistakable.

The lower division of the extra-drift loess we refer to the first episode of the first glacial epoch.

ART. XLII.—*On certain Measures of the Intensity of Solar Radiation;* by WILLIAM FERREL.

WHERE one thing in nature increases or decreases with another, either from the relation of cause and effect, or any other, the first cannot be regarded as a true relative measure of the second, unless there is strict proportionality in the increase or decrease of the two. The height of the mercury in a thermometer with reference to temperature, and in a barometer with reference to air-pressure, very nearly fulfills this condition, but not accurately so, and it is well understood that certain corrections have to be applied to the heights of the mercurial columns in both cases before they can be regarded as true measures of temperature in the one case, or of air-pressure in the other.

The mere differences of temperature indicated by the black-bulb thermometer exposed in the open air to solar radiation, and the air-temperature, without regard to absolute temperature or the commotions of the air, were once used as true measures of the intensity of solar radiation. But it was soon discovered that the uncertain effects of air-currents so changed the indications, that they were worthless as measures of this intensity. To obviate these effects the black-bulb was then placed in vacuo in a glass inclosure, and the differences between the temperatures of the black-bulb thermometer, and the air-temperature were regarded as true relative measures of the intensity of solar radiation, without regard to the absolute temperatures.

On account of the uncertainties of the air-temperatures, and the differences between them and those of the glass inclosure, an apparatus, called the *Arago-Davy actinometer*, consisting of a black and a bright-bulb thermometer in vacuo in glass inclosures, has been used, especially at the meteorological observatory at Montsouris, and the differences of temperatures indicated by the two thermometers, when exposed to the solar rays, without regard to absolute temperatures, have been used as true relation measures of the intensity of radiation.

It was first shown by the writer* that, in neither case, can the mere differences be regarded as true measures of the intensity of radiation; that not only are these differences not proportional to the intensity of the radiation for the same absolute temperatures, but that they differ very much for different temperatures, when the intensity of the radiation is the

* Temperature of the Atmosphere and the Earth's Surface, Professional Paper of the Signal Service, No. XIII; and Recent Advances in Meteorology; Report of the Chief Signal Officer for 1885, Part II, pp.375–380.

same, and formulæ were given for computing the true relative intensities from the observed absolute temperatures and their differences. Several other forms of apparatus of the same nature might be here named, used for the same purpose, and all affected similarly by the same cause of error. In all these instruments it is assumed, in accordance with what is called Newton's law, that the rate of radiation of any body, and so of its rate of cooling by radiation, is proportional to the differences of its temperature and that of the surroundings, whatever the absolute temperature may be, and so that these differences are true measures of the intensity of the radiation by which they are maintained. But this so-called law of Newton's was merely a first suggestion before experiments had been made to test its accuracy, and it is now known that it does not hold, with any degree of accuracy, through a range of 10° C. It is therefore remarkable that certain physicists, even in recent times, have extended this law up to the high temperature of the sun, and have thus obtained temperatures for that luminary, ranging from 10,000,000° C. down to much lower, but still very extraordinary temperatures, all based upon the assumption that Newton's law holds through so great ranges of temperature.

A modified form of the thermopile, called the *registering actinometer*, has been used for several years by M. A. Crova to determine the relative intensities of solar radiation. It is composed of two parallel disks, each one consisting of two metallic plates soldered together under pressure of $\frac{1}{50}$ of a millimeter in thickness and $0{\cdot}015^{m}$ in diameter, constituting a thermo-electric element fastened in a thin tube of brass; one of the junctions is in the dark, and the other receives a pencil of solar rays falling normally upon the blackened surface in the axis of the tube, which is provided with five diaphragms of aluminum of progressive decrease of opening down to the last, which is 4^{mm} in diameter. The opening of the tube is kept, by means of clock-work, accurately directed toward the sun during the day, and the amount of deflection of the galvanometer needle at any time, represented by a continuous curve of the registering apparatus, is taken as a true measure of the intensity of solar radiation. The following are some of the results obtained by this apparatus (Compt. Rend., ci, p. 418, August, 1885): "At sunrise the radiation increases with rapidity until nine or ten o'clock, an epoch at which it always attains its maximum, then it oscillates rapidly from one part to the other of its mean value, which diminishes on attaining a minimum at the time of greatest temperature, it then increases until about four o'clock without ever attaining the maximum

of nine hours, and then decreases regularly until the setting of the sun.

The smallest clouds and the least atmospheric disturbances are followed by oscillations of the curve. There is a great contrast between the apparent constancy of the light of the sun, and the continued oscillations of the curve, especially during a fair sky and calm weather."

Again the following deductions are made from the curves subsequently obtained after his first notice of the apparatus (Compt. Rend., cii, p. 962, April, 1886):

"1. The oscillations during the days of summer (with a very pure sky and without apparent clouds) are the more marked as the atmosphere is most calm and its temperature the highest; two maxima, the one before and the other after mid-day, are sufficiently distinct, the one from the other.

2. During the days of autumn the oscillations diminish in amplitude, and the maxima approach mid-day.

3. During the days of winter the oscillations persist, but their amplitudes still diminish more; the two maxima tend more and more to be confounded with each other.

4. In fine, during winter days, when the temperature is the lowest, and the mass of vapor contained in the air the least, the two maxima unite into one, which occurs at midday: with these conditions, especially if the atmosphere is strongly braced by violent winds, hourly curves are obtained almost entirely symmetrical with reference to the ordinate of mid-day."

Similar curves were subsequently obtained at places a long distance from the ocean, where the air was supposed to be much dryer than at Montpellier, where the first ones were obtained.

In this apparatus it is assumed that, for all temperatures, the intensities of the thermo-electric currents, indicated by the deflecting of the galvanometer needle, are proportional to the thermo-electric forces, that these are proportional to the differences of temperature between the two ends of the thermopile, and that these again, are proportional to the intensities of the solar radiation by which these differences are maintained, and so that the deflections of the galvanometer needle are proportional to the intensities of the radiation, and are consequently true relative measures of them. But none of these assumptions, it seems to the writer, is strictly correct.

By Ohm's law we have

$$I = \frac{E}{R} \tag{1}$$

in which I is the intensity of the thermo-electric current, E is the thermo-electric force and R is the resistance. In this ex-

pression E and R are functions of the temperature; and such that, for not very great ranges of temperature, we can put

$$E = C(1 + c\tau)\delta, \qquad R = R_0(1 + r\tau). \tag{2}$$

In the first of these the temperature τ is to be taken for the mean of the range δ, the difference of temperature between the two ends of the thermopile, and C and c are constants. In the latter R_0 is the resistance at the temperature $\tau = 0$, and r is a constant. With these values of E and R, we get

$$I = \frac{C(1 + c\tau)}{R_0(1 + r\tau)}\delta. \tag{3}$$

Hence I is not proportional to δ, except for a constant temperature, and for different temperatures there are different relations between I and δ.

Since δ is the change of temperature of the plate from being exposed to the sun's rays, and consequently the difference of temperature between the plate and the surroundings, its value, in a state of equilibrium or constancy, must be such, that the plate loses heat just as fast as it receives it from the sun. Now the loss of heat may be by radiation, conduction and convection, but is mostly by the former. The conduction of heat through the air becomes considerable, in comparison with the radiation of it, mostly in the case of curved surfaces only with small radii of curvature, as those of small thermometer bulbs and small wires, and is inconsiderable generally in the case of flat surfaces. But of course much depends upon the nearness of the surface to the surroundings receiving the heat; for the rate of radiation is independent of this. From the construction of the instrument there cannot be any sensible effect from convection currents, except perhaps from such as arise from the outside disturbances of the atmosphere in windy weather.

Considering here the effect of radiation only, we would have by the Newtonian law of radiation, the rate of losing heat by the plate, and so the intensity of solar radiation, proportional to δ for all temperatures and all ranges of δ, but this is not the case for any other law. By the law of Dulong & Petit, putting i for the intensity of solar radiation, we have

$$i = B\mu^{\tau}(\mu^{\delta} - 1) = B\mu^{\tau}(\mu - 1)\delta \tag{4}$$

in which $\mu = 1{\cdot}0077$ and B is a constant depending upon extent of surface and radiativity, and τ is reckoned in degrees of the Centigrade scale. The value of δ from this expression in (4) gives

$$I = \frac{C(1 + c\tau)}{R_0(1 + r\tau)} \cdot \frac{i}{B(\mu - 1)\mu^{\tau}}. \tag{5}$$

It is readily seen that the relation between I and i depends upon the temperature τ, and so is different for different temperatures, and consequently I cannot be regarded as a relative measure of i under all circumstances, but only when τ remains constant. For instance, the ratio between I and i is not the same when $\tau=0$, as in a summer temperature when $\tau=25°$.

If we put $I_\circ$ for the value of I when τ is equal to any assumed value $\tau_\circ$, and put

$$\Delta=\tau-\tau_\circ \tag{6}$$

we get from (5)

$$I_\circ=I\times\frac{1+c\tau_\circ}{1+c\tau}\cdot\frac{1+r\tau}{1+r\tau_\circ}\cdot\frac{\mu^\tau}{\mu^{\tau_\circ}}=I\times(1-c\Delta)(1+r\Delta)\mu^\Delta \tag{7}$$

in which the last form of expression is only approximate, but sufficiently accurate, unless Δ is large. Hence, in order to make the observed intensities I of the electric current measures of radiations it is necessary to reduce them to a common temperature $\tau_\circ$, which, in order to make Δ small, should be a medium temperature, or at least one not varying much from such a temperature.

With regard to the values of the constants c, r and μ, that of c differs with different metals forming the circuit, and may be either positive or negative. That of r is always positive, and differs but little in different metals. It was remarked by Clausius that the electrical resistance of all chemically pure metals should be proportional to the absolute temperature, and if so, we should have $r=\cdot00366$. Experiment very nearly verifies this law, but mostly makes the increase of resistance in a ratio a little greater. We shall therefore put

$$r = 0\cdot0038 \tag{8}$$

The value of $\mu=1\cdot0077$ given above was obtained from experiments made through a range from 80° to 240° C., but it has been shown by the writer* that for lower temperatures it must be much greater, the value at 50° C. being about 1·0088, and for still lower temperatures it should be considerably greater.

According to Stefan's law of radiation, we have

$$i = KT^{e-1}\delta \tag{9}$$

in which $e=4$, K is a constant, and T is the absolute temperature. The value of δ from this expression, substituted in (3), gives

$$I_\circ=\frac{C(1+c\tau)}{R_\circ(1+r\tau)}\cdot\frac{i}{KT^{e-1}} \tag{10}$$

* This Journal, vol. xxxviii, July, 1889.

From this we get, proceeding in the same manner as in the preceding case,

$$I_0 = I \times \frac{1+c\tau_0}{1+c\tau} \cdot \frac{1+r\tau}{1+r\tau_0} \cdot \left(\frac{T}{T_0}\right)^{e-1} = I \times \left\{ 1 + \left(-c + r + \frac{e-1}{T_0} \right) \varDelta \right\} \quad (11)$$

the latter form of expression being sufficiently accurate where $\varDelta = \tau - \tau_0$ is not very large.

From this expression it is seen that the observed electric intensities, indicated by the deflections of the galvanometer needle, must be multiplied into a factor which is a function of $\varDelta$ and T_0, in order to reduce them to I_0, the intensities which would have been observed if the apparatus had remained at the same temperature τ_0, or corresponding absolute temperature T_0. The two metals used in the thermoelectric circuit of Crova's apparatus are unknown to the writer, but we will suppose, for the sake of illustration, that they are iron and copper. In this case we should have $c = -\cdot 00366$. The value of $e=4$ of Stefan's law has been shown by the writer, in the paper already referred to, to be too large for ordinary air temperatures, and he has given the following formula for computing its value for any given temperature τ:

$$e = 3 + \cdot 00032\,\tau + \cdot 00032 \frac{T \log T}{M} \quad (12)$$

in which M is the modulus of common logarithms. For $\tau = 15°$, this gives $e = 3\cdot 53$ very nearly, but the value varies very little throughout the usual range of working temperatures. With these values of c and e, and that of r in (8), we get from (11), with $T_0 = 272 + 15 = 288°$,

$$I_0 = I \times (1 + (\cdot 00366 + \cdot 0038 + \cdot 0088)\varDelta) = I \times (1 + \cdot 01526\varDelta) \quad (13)$$

In this expression if we assume the temperature τ_0 in (6) from which $\varDelta$ is reckoned to be that of 10 o'clock. Then the values of $\varDelta$ for the hours preceding that hour would be negative, and after that hour positive, in all ordinary cases of fair weather, and hence the observed values of I would be decreased before 10 o'clock and increased after that hour, and it is readily seen that this would tend to throw the maximum at least toward midday, and to fill up the observed depression in the afternoon. It does not appear adequate, however, to render the forenoon and afternoon curves symmetrical, and at least a considerable part of the effect which destroys this symmetry is undoubtedly to be attributed to the different hygrometric conditions of the air in the forenoon and afternoon. But both effects are in the same direction and have the same epochs of maxima and minima, so that there is no way of separating them and determining how much belongs to each. But even

with the correction given by the preceding formula the lack of symmetry between the forenoon and afternoon branch of the curve is greater than that in such curves generally from other means of measuring the intensities, though these are generally, though not always, less in the afternoon than in the forenoon.

It is perhaps doubtful whether Crova's curves, rightly interpreted, would really give as much depression in the afternoon as is inferred. From 10 o'clock on, through most of the afternoon, the oscillations of the curve about the medium line are very great, and such a line seems to have a great depression, and even a second maximum; but as the lowest points of the curve represent only the exceptionable states of the atmosphere, which are perhaps of comparatively short duration, the curve representing the average intensities would have to be drawn higher up, nearer to the upper extremes of the oscillations. These oscillations, also indicated by the bolometer, are undoubtedly caused by what may be called invisible clouds, the atmosphere during the warmer part of the day being in an unstable state, in which local ascending currents are formed and the vapor contained in them, in cooling, does not quite arrive at the state of saturation and condensation; or if so, the condensation is not quite sufficient to cause a visible cloud at great altitudes, as is frequently the case when numerous small patches of cumulus cloud are formed.

It is evident from an inspection of (11), that the observed values of I in summer and in winter, or in low latitudes and high latitudes, or low and high altitudes, or in any circumstances in which there is a difference of temperature, are not comparable without a reduction to the same temperature. For instance, using (13) instead of the first expression, though not very accurate for large values $\Delta=\tau-\tau_0$, and supposing Δ to be equal to 20°, we get $I_0=1{\cdot}305\ I$, so that the observed value at the temperature τ, must be increased nearly one-third to make it comparable with one observed at the temperature τ_0, according to the formula above. But it is not to be understood here that this formula, with the numerical constants used, is claimed to be a correct reduction, but simply one which gives roughly the order of reduction which may be required, and it is given rather as an illustration merely, than as a correct formula of reduction, even in the case in which iron and copper are used in the thermoelectric circuit. For other metals, of course, the formula would be different. Some allowance, also, must be made for the effects of neglected conduction and convection.

In the *bolometer* the deflection of the galvanometer needle is proportional to the differences of temperature of the bolometer strips, and so the first two factors into which I in (11) is multiplied disappear. But there are the same relations between

these very small temperature differences and the corresponding intensities of radiation which produce them, as in the case of the exposed plate in the registering actinometer; so that the higher the temperature, the greater the amount of solar or other radiation required to raise the temperature of the strips a given very small amount, which we have denoted by δ. By the law of Dulong and Petit the relation between i and δ for any given temperature τ is given by (4), but by Stefan's law it is given by (9). Proceeding as before, except neglecting the terms containing c and r as factors, we get, with the relation of Stefan's law, instead of (11),

$$I_0 = I \times \left(\frac{T}{T_0}\right)^{e-1} = I \times \left(1 + \frac{e-1}{T_0} \varDelta\right) \qquad (14)$$

the latter form being only approximate and not very accurate where $\varDelta$ is large. It is seen, therefore, that the observed intensities I, in order to be comparable, must be multiplied into a factor which is a function of the temperature in order to reduce them to what they would have been with an absolute temperature equal to T_0. Or, if we wish to reduce the observed value of I_0 at temperature T_0 to that of I at temperature T, we must divide by this factor.

From Langley's Researches on Solar Heat, Tables 108 and 110, p. 136, we get the following average values of the sums of all the deflections of the several wave-lengths, namely: for Lone Pine 710, and for Mountain Camp 1284, using only the observations of September 2 and 3 in the latter. These are the uncorrected deflections, to which large corrections have to be applied, especially to those of the shorter wave-lengths, but the corrected results must give nearly the same ratio between Lone Pine and Mountain Camp. Langley found from actinometer observations that the intensities of solar radiation at Mountain Camp were about one-ninth greater than at Lone Pine. Increasing, therefore, 710 by one-ninth, we get 789 for what the sum of the deflections at Mountain Camp should have been, if they are proportional to the intensities of the radiation below and above, instead of 1284. Now this is much too great a difference to be all due to difference of temperature, according to the formula of (14). Temperature observations at Lone Pine and Mountain Camp, which are required for an application of the formula, are not given, except in one case it is stated that the temperature of the galvanometer at Lone Pine was 97° F. But from observations of wet- and dry-bulb thermometers about the same time for hygrometric purposes, it may be inferred that the differences of temperature between Lone Pine and Mountain Camp could scarcely have been as much as 20° C. Using this for the value of $\varDelta$ in (14), and

$T_{\circ}=286°$, which was about the absolute temperature at Mountain Camp, and $e=3{\cdot}53$, as previously determined, we get $I_{\circ}=1{\cdot}185\ I$, that is, by the formula, the intensities at Mountain Camp should be increased over those made at Lone Pine at a higher temperature and then reduced for difference of level to Mountain Camp, in the ratio of 1 : 1·185. But we have seen that the bolometer observations make this in the ratio of 789 : 1284 or 1 : 1·63. Observations, therefore, indicate that in the case of both the registering actinometer and the bolometer, a reduction for difference of temperature is required, but what is perplexing in the matter is, that the reduction required, especially in the case of the bolometer, is much greater than that given by the preceding formulæ of reduction.

It is not to be understood that this is a matter which affects any of Langley's results, for he used the bolometer to determine the relative intensities only of the several different wavelengths, which were all made at the same times for each series, and consequently at the same temperatures.

In what precedes, the writer wishes to state in conclusion, that he has ventured with considerable timidity upon unfamiliar ground, and that it is possible he may have made some blunders. If so, it will be matter for discussion and correction.

Martinsburg, W. Va., Jan. 7.

Art. XLIII.—*Geological Age of the Saganaga Syenite;* by Horace V. Winchell, F.G.S.A.

The Saganaga Syenite is an area of syenitic and granitic rocks occupying largely the shores and islands of the lake called by the Ojibways *Kasaganaga* (the lake with many islands or the lake surrounded by thick forests, as differently interpreted), which lake is situated on the international boundary line between Minnesota and Ontario, and has many long arms extending north and south from the line. This syenite is also found around Sea Gull lake, and occupies an area of about 100 square miles in the State of Minnesota, in townships 65 and 66 north, ranges 4 and 5 west of the fourth principal meridian. The hills surrounding these lakes rise to a height varying from 100 to 300 feet, and consist of bare glaciated knobs of syenite. These hills are apparently the northeastern prolongation of the Giants' Range, a mountainous range of syenitic rock extending in a general northeast direction from the Mississippi River to the Canadian boundary line.

The general composition and structure of the syenite have been fully described in the Sixteenth Annual Report of the

Minnesota Geological Survey, pp. 211–233. The prominent macroscopic characters are described as follows: "wherever the Saganaga syenite is traced large grains of quartz constitute a distinctive character. These grains are large, angular and numerous, and on weathered surfaces stand out prominently. The feldspar exists in subangular patches, imbedded with the quartz in a ground mass which is mostly chloritic, and in places develops chlorite spots, while in other places hornblende forms emerge into visibility. So, apparently, a syenite appears or disappears. These characters I have learned to recognize as the borderland between schistic and gneissic areas."* Again, considerable quartz is mentioned as occurring in this rock in some parts of the region. On page 215 of the same report, we find it stated that white quartz is seen in considerable abundance, some being in veins one or two inches in diameter, but mostly resulting from the excessive abundance of the usual quartz grains. These are said to be "very unevenly disseminated through the syenite, sometimes aggregated, and in places nearly wanting. The rock itself is not of course a characteristic syenite. All hornblende has disappeared. A feldspathic matrix remains, with some green specks and spots, and the quartz is imbedded in it; some of the broken surfaces of the rock have a sericitic luster. The formation on the whole appears roughly bedded with a dip of 63°." The general strike is N. 70° E. The syenite of Saganaga lake is also found to be conglomeritic in places, and contains pebbles which are strikingly similar to each other in composition and appearance. They are said to be "quite uniform in lithological aspect. They are uniformly dark colored, and in a rough way would be called greenstones." If it were not for the difference in color between the so-called pebbles and the matrix in which they are imbedded, we should be inclined to consider this as an agglomerate similar to those so numerous in the Keewatin and so characteristic of it. A majority of the "pebbles" are composed of lamellar augite with or without apparent small grains of feldspar. There are no pebbles of syenite or jasper and no sedimentary fragments.

The significance of the facts mentioned above will become apparent in the course of this paper. Before educing any conclusions from them however, it is desirable to mention a few further observations made by the writer in the latter part of October, 1890. The observation of greatest importance and which it is believed has never before been made in this region, was the discovery of a band of chalcedonic silica, one and one-half inches in diameter, and about three feet in length in the

* A. Winchell, 16 Minn. Rep., p. 214.

syenite of the Saganaga region. This phenomenon may be seen at the end of a portage on Granite river, which forms the international boundary line between Gunflint and Saganaga lakes. This band of silica is perfectly straight and so clearly exposed that it is surprising that it has not been noticed before. It has an east and west direction corresponding to the general strike of the rocks in this region, and to the observed foliation and coarse-bedded structure sometimes noticed in the syenite. It stands vertically in the pink crystalline rock, and has along one side a streak of greenish chloritic matter only a fraction of an inch in thickness.

The significance of this ribbon of chalcedonic silica in crystalline syenite may be more clearly perceived if we consider the nature and origin of this particular kind of silica as elucidated from the rocks of Keewatin age, and studied for several years in northern Minnesota. The method of formation of this peculiar variety of quartz has been outlined in a paper entitled: "On a possible Chemical origin of the Iron Ores of the Keewatin in Minnesota," by N. H. Winchell and H. V. Winchell, read Sept. 2, 1889 at the Toronto meeting of the A.A.A.S., and has been treated in all fullness of detail as to structure, chemical and petrographical characters in a forthcoming bulletin of the Minnesota Geological Survey on the Iron Ores of Minnesota. In the article and bulletin referred to it is shown that this quartz, which forms the siliceous part of the jaspilyte associated with the iron ore deposits, is amorphous and non-crystalline. It is associated directly with rocks of igneo-aqueous origin, and was formed by chemical precipitation from heated oceanic waters at a very early stage of the world's history. It mingles with the volcanic ashes and lavas of the Keewatin in amounts varying from a fraction of a per cent to almost absolutely chemically pure silica. It is a striking and unique characteristic of the rocks of the Keewatin age, and has only to be seen to be recognized even in such peculiar associations as in the Saganaga syenite. Wherever found it indicates solution and oceanic deposition.

Leaving chalcedonic silica for a moment, let us consider another set of facts noticed in the Saganaga syenite area. On the north side of Saganaga lake in Ontario, the rock composing the shore is found to consist largely of greenish feldspathic and sericitic schists and agglomerates. The syenite passes into these earthy schists directly, without the usual intervening schists of the Vermilion age. So frequent and so varied are the changes from syenite or chloritic syenite gneiss into thick bedded or almost massive ridges of Keewatin rock that the conclusion is inevitable that they are not separate formations, but that the metamorphism of the schists has been more in-

tense in certain belts of country, and the syenite is simply the result of this intensity. This phenomenon of locally intensified metamorphism may be easily accounted for if we remember that pressure alone cannot develop heat, but pressure together with motion produces intense heat at the planes where the motion takes place.* Thus if the Keewatin strata at Saganaga were folded at an early period, so as to stand up vertical, the lateral pressure would not effect one portion of the rocks more than another. But if this lateral pressure were accompanied by a slipping of some ridges up and of others down, the result would be ridges slightly altered alternating with highly metamorphosed Keewatin strata. For a space of several miles along the north side of the lake this condition of affairs is noticeable. The ridges of Keewatin green schist, and of syenitic rock rise in bare alternating or intermingling ranges of varying width and altitude, but generally of such narrow width, that there are half a dozen such transitions in the space of a quarter of a mile. At a short distance it is impossible to say whether the rock ahead is more like Keewatin green schist and agglomerate, or the syenite peculiar to the southern half of the lake. The agglomeritic structure is almost universal in the hills a short distance north of the lake shore, and suggests again the idea that the wonderful syenite conglomerate may be only a Keewatin agglomerate highly altered locally. This is not at all unreasonable, for the bowlder forms in the green schist are neither so much altered structurally by the assorting agency of the ocean in which they fell as volcanic bombs, nor so acidic by reason of the intermingled chalcedonic silica as the surrounding rock, and hence would remain as green "pebbles" under metamorphism sufficiently intense to convert the matrix into syenite.

The presence of chalcedonic silica in the Saganaga syenite together with the structural relations existing between the non-crystalline Keewatin schists, and the crystalline syenite supposed to be of Laurentian age amount almost to conclusive proof that the materials of which the syenite is composed are not Laurentian but Keewatin in age. The presence of the numerous and large quartz grains mentioned above as being characteristic of the syenite of the Giant's Range may now be easily explained when we consider the immense amount of chemically deposited chalcedonic silica in the Keewatin. The same metamorphism, which by hydro-thermal fusion and pressure formed the orthoclase and hornblende from the other ingredients has been sufficient to crystallize most of the silica into large grains.

* O. Fisher, Physics of the Earth's Crust, 1889, p. 2.

That this metamorphism was of very early date, we are confident because the syenite is found to underlie unconformably the quartzites and slates of the Taconic or Huronian. The change from non-crystalline to crystalline was probably produced at the time of the folding of the earth's crust which turned both the Keewatin green schist and the Keewatin syenite up on edge so that they stand vertical over a large part of northern Minnesota.

If the Saganaga syenite be as supposed, the northeastern extension of the Giant's Range, then this whole belt of rock from the Mississippi river to the Canadian boundary and beyond must be Keewatin and not Laurentian. And indeed there are indications from the relations of the Giant's Range syenite to the vertical green schists on the south of the syenite as seen near Hinsdale on the Duluth & Iron Range R. R., that this is a correct inference. If this extensive range of gneissic rock which has generally been supposed to be Laurentian is then not truly Laurentian but Keewatin, it seems likely that in the latter we have a rock come down to us unchanged through all the ages, which in its various phases represents the original fire crust of the earth more nearly than any other known rock. But this is a question to be discussed at some future time.

In closing, I wish to suggest an economic bearing of this question. If the Saganaga syenite be of Keewatin age, and contain chalcedonic silica in an original unchanged condition, it is not unlikely to contain also Keewatin iron ore deposits free from titanium, and of high grade in other respects. It can thus no longer be laid down as a law for explorers in the northwest that the gneisses contain no iron ore deposits. It is believed that the non-titaniferous magnetites of New York and eastern Canada afford good illustrations of this class of iron ores, and that they have been changed from chemically precipitated hematites of Keewatin age.

December 20th, 1890.

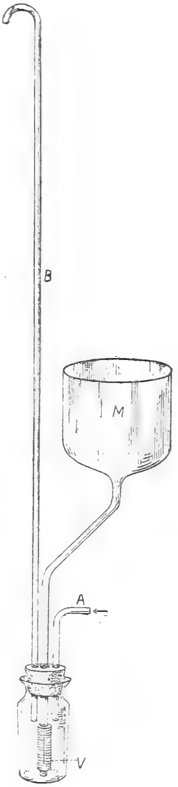
ART. XLIV.—*On a Self-feeding Sprengel Pump*; by H. L. WELLS.

THE arrangement here described for raising mercury continuously to the top of a Sprengel pump, or for other purposes, may be of use or of interest to some chemists and physicists. The method, though exceedingly simple, seems to be new.

Fig. 1 shows the apparatus in its simplest form. Water

under pressure is admitted at A, it flows into the small bottle, then up through the tube B. On the tube of M, in the bottle, is a valve V which allows a liquid to flow into the bottle, but closes when the pressure is in the opposite direction. Now if mercury is placed in the reservoir M it will flow down into the bottle, provided the column of mercury more than counterbalances the column of water in B and the pressure caused by the friction of the current passing through it The conditions just mentioned are easily attained by making the mercury column about one-fifth or one-fourth the height of the water column and regulating the flow of water so that the friction is not very great. Under these circumstances the mercury rises in the tube B to a height somewhat less than its level in M, the valve then closes, and, if the bore of this tube is not too great, the mercury which has risen in it must be carried up to the top by the current of water. As soon as this mercury is forced out at the top of B, the valve opens again and the whole operation is repeated.

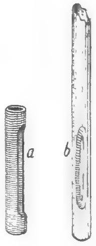
1.



This apparatus, which may be called a mercury elevator, must be seen in operation to be fully appreciated. It works rapidly and with great efficiency, and the automatic action of the valve makes it an interesting piece of physical apparatus.

Two forms of valves have been used with good success. The well-known Bunsen valve is shown at V in fig. 1. For this purpose it should be made of a quite heavy rubber tube so that it will not collapse under the pressure. Another form of valve is shown in fig. 2, which is perhaps somewhat preferable since it cannot collapse under the pressure, and if properly constructed it delivers mercury more promptly than the other. It is made by grinding a rather thin-walled glass tube on a grindstone until a narrow opening is made as shown in *b*; a soft, rather thin rubber tube, fitting the glass tube snugly, is cut as shown in *a*, somewhat less than half the section of the tube being cut away. The rubber tube is then drawn over the glass tube so that the openings are on opposite sides. Whichever valve is used, care must be taken to have it large

2.



enough to deliver mercury rapidly, for otherwise the efficiency of the apparatus will suffer.

3.

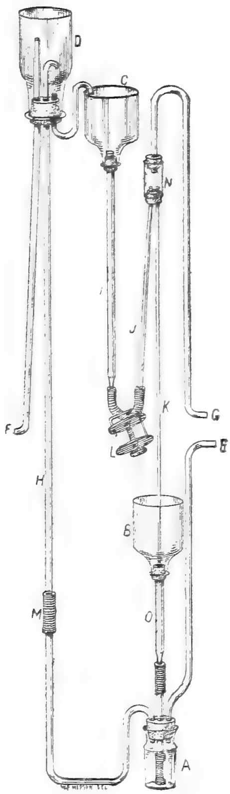


Fig. 3 represents a Sprengel pump, with the mercury elevator, now in use in this laboratory. The artist has relatively shortened most of the tubes, and has exaggerated some parts of the apparatus for the sake of clearness of detail.

The whole apparatus can be easily constructed with the materials usually at hand in a chemical laboratory. Water enters at E, carries mercury up through H and overflows through F, while the mercury goes through a trap into the reservoir C of the Sprengel pump.

The total height of the apparatus is 2400^{mm}. The bore of the tubes E, H and F is $5–6^{mm}$. The tube H, where it leaves the bottle A, takes a downward curve, thus increasing the length of the intermittent column of mercury raised. The inverted siphon* formed by the tubes I and J prevents air, water or sulphuric acid, which may be in C, from being carried over into the pump proper, no matter how slowly mercury may be delivered. I has a bore of $8–10^{mm}$ and is 900^{mm} long; J is 850^{mm} long with a bore of $3\frac{1}{2}^{mm}$.

The Sprengel tube K is about 1500^{mm} long with a bore of 3^{mm}. It is very important for the sake of rapid pumping, that this "fall-tube" should be long and have a bore as large as consistent with good working.† If this tube is larger at one end than the other, as it may be advantageously, the smaller end should be uppermost, because it is at the top, if anywhere, that mercury fails to fill the bore of the tube, and also because this form of tube prevents the atmospheric pressure from forcing a column of mercury upwards out of it, since the column lengthens when it rises.

* A Sprengel pump with this modification is described and figured in Sutton's "Volumetric Analysis," edition of 1871, p. 262.

† The proper caliber of the fall-tube is given by Sprengel (Jour. Chem. Soc., 1865, p. 15) as $2\frac{1}{2}^{mm}$. He says that with larger tubes his vacuua were $\frac{1}{2}–1^{mm}$ less than the barometric height, hence where the most perfect exhaustion was required it would be advisable to use a tube of the size which he gives. Sprengel limited the length of his fall-tube by the height at which it was convenient to pour back the mercury into the reservoir at the top, but it is evident that much longer fall-tubes could be used conveniently with the "mercury elevator."

The tube N* is about 50^{mm} long, and 12^{mm} in diameter, and is surrounded by a larger tube, not shown in the figure, which is closed at both ends with rubber stoppers and filled with concentrated glycerine.† This glycerine may be replaced by mercury where moisture in the exhausted space is to be carefully guarded against.

The tube G, with which the vessel to be exhausted is connected, is of rather heavy glass with a small bore. The highest point of its curve at the top should be above any possible level of mercury in the reservoir C. The tube O has a bore of $8–10^{mm}$ so that it may readily fill with mercury, while its prolongation, to which the valve is attached, has a bore of about 6^{mm}. The height of B above A determines the amount of mercury raised by a given stream of water. In the present apparatus this height is 500^{mm}, and it is sufficient to work the pump rapidly, but where a sufficient water-pressure was available, it would perhaps be better to increase this to 600^{mm} or more, with a corresponding addition to the height of the whole apparatus. It is evident that the height of this reservoir above the valve-bottle should be considerably less than the column of mercury which the head of water at disposal will raise by direct pressure. This water-pressure, in the case of an apparatus of the dimensions just described, is less than necessary to run an ordinary water-jet pump at its best efficiency; in fact, this apparatus was devised in order to overcome the difficulties, due to varying water-pressure in this laboratory, which were experienced with the water-pump in distilling under diminished pressure, and it may be mentioned that the apparatus has been very successful for this purpose. The bottle A should be as small in diameter as convenient for making the attachments, and its stopper should be securely wired down before putting on the pressure.

The support to which the apparatus is attached is an upright board 300^{mm} wide with a base about 600^{mm} square. The reservoirs B, C and D are securely set into the board in such positions that the various tubes rest against its surface.

To start the action of the apparatus a slow stream of water is first started through it, then mercury is poured in at B. A trial will determine approximately the best speed at which to run the water.

When the use of the pump is to be discontinued the clamp L is first closed and the excess of mercury, which need be only a small quantity, is allowed to be carried up into C before

* A connection of this kind for a Sprengel pump is described by Johnson and Jenkins, Am. Chem. Jour., vol. ii., p. 29.

† A joint surrounded by glycerine for this purpose is described by Frankland and Armstrong, Jour. Chem. Soc., 1868, p. 91.

stopping the water-current. If, at starting, the excess of mercury remaining in A and the tubes connected with it is so great that the water-pressure cannot lift it out of the tube H, it will be necessary to disconnect the rubber tube M and force out the excess of mercury at this point by means of the usual stream of water.

The mercury delivered into the Sprengel-tube may carry traces of water with it, particularly when there is water in the reservoir C and when, at the same time, mercury is allowed to run through the pump faster than the elevator is raising it, so that the mercury-level sinks to a low point in the tube I. In this case water-vapor can be guarded against by placing concentrated sulphuric acid in C.

Sheffield Laboratory, New Haven, Conn., March, 1891.

ART. XLV.—*Contributions to Mineralogy, No. 50;* by F. A. GENTH; *with Crystallographic Notes* by S. L. PENFIELD and L. V. PIRSSON.

1. ON THREE NEW VARIETIES OF AXINITE.

a. Axinite from Franklin, New Jersey.

THE specimens for examination were received from Messrs. Geo. L. English & Co. The axinite, both, in crystals and laminated masses, is found, as a great rarity, associated with a beautiful rose-colored variety of fowlerite, polyadelphite, biotite and barite. The crystals are of a beautiful honey-yellow or pale greenish yellow color, from about 1^{mm} to 5^{mm} in size. Spec. grav. of the crystals = 3·358, of the laminated masses = 3·306.

The axinite crystals are of interest as they have a very unusual habit and also possess some rare planes.

The forms which have been observed are as follows, using Naumann's position.

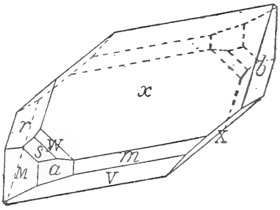
a, 100, i-$\bar{\imath}$	m, 1$\underline{1}$0, I'	x, 1$\underline{1}$1, $-1'$	s, 201, -2-$\bar{\imath}$	X, 0$\bar{2}$1, 2-$\breve{\imath}$
b, 010, i-$\breve{\imath}$	M, 1$\bar{1}$0, I	r, 1$\bar{1}$1, -1	W, 312, $-\frac{3}{2}$-$\bar{3}'$	V, $\bar{1}\bar{1}$2, $\frac{1}{2}$

As seen in figure 1 the crystals are tabular from an unusual development of the x faces, giving a habit unlike anything which the authors are familiar with in this species. The face W, 312, is well developed and is new. It was readily determined by measurement and its occurrence in the zone $M\ s\ x$. V, $\bar{1}\bar{1}2$, is a rare form which is not given by Goldschmidt* or Frazier† in their lists of axinite planes. It is

* Index der Krystallformen. † This Journal, III, xxiv, p. 439.

however mentioned by Schrauf, as the pyramid μ, 131, of his position, and shown on a crystal from Miask, Ural, in figure 16 of his Atlas. X is also a rare plane observed by vom Rath* in crystals from Botallack, Cornwall. It is the brachypinacoid b of vom Rath and Schrauf. The two rare planes V and X are very prominent on the Franklin crystals as seen in the figure. All the faces have a fine luster and gave good reflections of the signal on the goniometer. The planes in the zone M, s, W, x are striated parallel to their mutual intersections and the measurements in this zone were therefore not so exact as the others. Some of the important measured and calculated angles are as follows, using the following elements, $\breve{a} : \bar{b} : \dot{c} = 0{\cdot}49211 : 1 : 0{\cdot}47970$:

1.



$\alpha = 82° \; 54' \; 13''$ $\beta = 91° \; 51' \; 43''$ $\gamma = 131° \; 32' \; 19''$

		Measured.	Calculated.			Measured.	Calculated.
$x \wedge r$,	$111 \wedge 1\bar{1}1 =$	40° 48′	40° 46′	$m \wedge a$,	$110 \wedge 100 =$	15° 25′	15° 34′
$r \wedge b$,	$1\bar{1}1 \wedge 0\bar{1}0 =$	93° 22′	93° 21′	$a \wedge M$,	$100 \wedge 1\bar{1}0 =$	28° 8′	28° 55′
$r \wedge X$,	$1\bar{1}1 \wedge 0\bar{2}1 =$	68° 24′	68° 24′	$m \wedge V$,	$\bar{1}\bar{1}0 \wedge \bar{1}\bar{1}2 =$	45° 8′	45° 11′
$r \wedge m'$,	$1\bar{1}1 \wedge \bar{1}\bar{1}0 =$	115° 37′	115° 38′	$x \wedge s$,	$111 \wedge 201 =$	16° 5′	16° 7′
$m \wedge s$,	$110 \wedge 201 =$	27° 51′	27° 57′	$x \wedge M$,	$111 \wedge 1\bar{1}0 =$	48° 46′	48° 25′
$b \wedge m$,	$010 \wedge 110 =$	32° 48′	32° 47′	$x \wedge W$,	$111 \wedge 312 =$	9° 8′	9° 22′

All of the above measurements were made on one crystal about 2mm in its greatest diameter.

The material for the analyses was dried over sulphuric acid; the boric acid was determined by Gooch's method by distillation with methyl alcohol. The following results were obtained:

	Crystals.	Laminated.	
	1.	2.	3.
Ignition ... =	0·76	0·40	0·41
SiO_2	42·77	42·47	42·28
B_2O_3	5·10	5·05	not det.
Al_2O_3	16·73	16·85	16·88
Fe_2O_3	1·03	1·16	1·36
PbO	----	0·09	----
CuO	0·12	0·11	1·57 (CuO + ZnO)
ZnO	1·48	1·53	
MnO	13·69	13·14	12·97
MgO	0·23	0·26	0·17
CaO	18·25	18·35	19·54
	100·16	99·41	

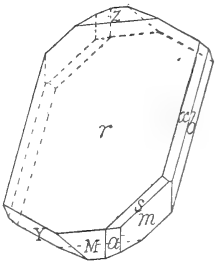
As might be expected from this locality the mineral contains a higher percentage of manganese than has ever been observed before as well as some zinc.

* Pogg. Ann., cviii, p. 243.

b. Axinite from Guadalcazar, Mexico.

The material for examination was kindly presented by Messrs. Geo. L. English & Co. The axinite is associated with a white feldspar, in part altered to kaolinite; it is found in minute crystals, the largest not over 5^{mm} in size, and granular scaly masses, the individual scales from $1–2^{mm}$. The color is brownish to greenish gray of various shades (sage color). Spec. grav. $=3{\cdot}299$.

2.



These crystals are tabular parallel to the pyramid r, $\bar{1}\bar{1}1$, fig. 2. The faces are usually curved and uneven and some of them are striated, a and m parallel to their intersection and r parallel to the zone $M\,r$, so that the crystals are not suited for exact measurement on the goniometer. The following forms were identified by measurements, which seldom varied more than half a degree from the calculated.

a, 100, i-$\bar{i}$	m, 110, I'	r, $1\bar{1}1$, -1	z, $1\bar{1}2$, $-\frac{1}{2}$
b, 010, i-$\breve{i}$	M, $1\bar{1}0$, I	x, 111, $-1'$	Y, $\bar{1}31$, 3-$\breve{3}'$
c, 001, O	s, 201, -2-$\bar{i}$	e, $\bar{1}11$, $1'$	n, $1\bar{3}1$, -3-$\breve{3}$

Of these c, e and n, not represented in the figure, on most of the crystals are either wanting or very small: s and x are small and frequently wanting: the other forms are quite constant, about as represented in the figure.

The larger crystals did not yield very good material for analysis as they are often too intimately mixed with feldspar; the granular variety however was in places almost pure, containing only traces of kaolinite from which it was easily purified. The analysis gave:

Ignition	$=$ 0·75
SiO_2	42·85
B_2O_3	5·17
Al_2O_3	16·96
Fe_2O_3	5·00
CuO	0·19
MnO	9·59
MgO	0·87
CaO	18·49
	99·87

There were two minute crystals associated with this axinite, one of white color in pyramids, apparently quadratic; the other black, neither of which could be identified.

c. Axinite, from McKay's Brook, which empties into the N. E. Mirimichi River, Northumberland Co., N. S.

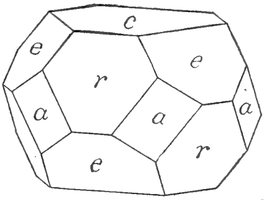
Only one small fragment of about 15×10^{mm} in size, received from Mr. Samuel Hufty in Camden, N. J., consists of very small brown and brownish gray tabular crystals, arranged to form a somewhat columnar granular rock. The crystals are too imperfect for satisfactory measurements, a qualitative chemical examination proves the mineral to be axinite.

2. On Eudialyte from Magnet Cove, Ark.

The material for this and the following mineral was also kindly furnished by Messrs. Geo. L. English & Co.

The following observations on the eudialyte from Magnet Cove had been made when we received the article on eudialyte and eucolite from Magnet Cove, by J. Francis Williams, in the December number of this Journal, 1890. The crystals agree in every respect with the description given by Williams. Only the simple forms c, 0001, O; r, $10\bar{1}1$, 1; e, $01\bar{1}2$, $-\frac{1}{2}$ and a, $11\bar{2}0$, i-2, were observed. These were developed as shown in fig. 3. One crystal about $2\frac{1}{2}^{mm}$ in diameter was measured in which the mean of six independent measurements of $c \wedge e = 50° \ 44'$, and five of $c \wedge r = 67° \ 35'$. Williams calculates for these $50° \ 43'$ and $67° \ 45\frac{1}{2}'$ respectively, using $a : \dot{c} = 1 : 2{\cdot}1174$.

3.



The analyses from a want of crystallized material had to be made with the massive rose-colored of lighter and deeper shades, scarcity of either prevented making separate analyses of each; examination under a strong lens showed no impurity. Sp. gr. = 2·810.

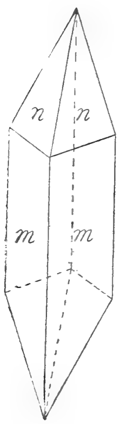
The analyses gave:

		1.	2.
Ignition	=	1·88	1·84
Cl		1·42	1·41
SiO_2		51·83	51·68
ZrO_2		11·45	11·62
Ta_2O_5 (?)		0·39	0·29
FeO		4·37	4·35
MnO		0·37	0·30
MgO		0·11	0·07
CaO		14·77	15·05
Na_2O		13·29	----
K_2O		0·43	----
		100·31	

The material for these analyses was not as good as desirable. It was obtained from the massive variety, occurring in rounded

particles, the largest of about 10mm diameter, disseminated through a mixture of feldspar and zeolites, and associated with ægirite, astrophyllite, titanite, etc. On account of its scarcity, the material, though selected with care and apparently free from admixtures, was not of uniform color, some particles being of a deep rose color, while others were of a much paler shade. It is not impossible that the latter have already suffered a partial alteration.

4.



3. On Titanite from Magnet Cove, Ark.

One of the rarer minerals of Magnet Cove is titanite. It occurs, associated with ægirite, orthoclase (or microcline) elaeolite, one or two zeolites, eudialyte and others in small pale brownish yellow or brown crystals. Sp. gr.=3·457.

The crystals are very simple and show a combination of the two forms *m*, 110, I and *n*, 111,−1, as in figure 4. The faces gave very poor reflections, so that only approximate measurements could be made.

The analysis gave:

Ignition	=	0·57
SiO_2		30·84
TiO_2		39·35
FeO		0·73
MgO		trace
CaO		28·26
		99·75

4. *Monticellite.*

Among the specimens from Magnet Cove, Ark., sent to me for identification by Messrs. Geo. L. English & Co., I observed the very rare species Monticellite. It is found in crystals and crystalline grains in a coarse-grained calcite, the individual grains of which are from 2 to 15mm in diameter, and is associated with small crystals of magnetite, rarely over 3mm in size and apatite, in microscopic colorless hexagonal prisms, but generally in crystalline radiating masses sometimes over 10mm in diameter. Mr. L. V. Pirsson has very kindly examined the crystals and gives in the following the results of his observations:

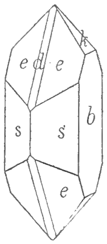
The crystals are not well adapted for accurate measurement, the faces being roughened in some places and in others lacking the polish on the crystal planes. A few faces gave moderately good reflections and on others by using the δ ocular of Websky, enough light could be condensed to give in a number of cases,

a fair image of the signal. These yielded moderately good measurements. Others however are only approximate from a "schimmer" measurement. The forms observed on two crystals which were measured are:

b,	010	*i*-ĭ	*k*,	021	2-ĭ
s,	120	*i*-2̆	*d*,	101	1-ī
m,	110	I	*e*,	111	1

The brachypinacoid is quite largely developed and also the brachydome 2-ĭ, and in these respects the crystals differ from those of the European localities. The habit is that of a short prism with pyramidal terminations as will be seen by reference to the figure. This crystal whose figure is given is about 3 ctm. in height, nearly 2 ctm. in breadth, parallel to the brachy-axis and a little more than 1 ctm. wide.

5.



The other crystal is characterized by the presence of the unit prism, in other respects it is quite similar to the one figured. The following table of calculated, and measured angles is appended to show the identification of the forms. For calculating the theoretical angles the axial ratios of vom Rath* have been taken, the lengths of the vertical and brachy-axes as given by him being halved, to bring them in accord with those of the chrysolite group, to which the mineral belongs.

These ratios are then,

$$a : b : c :: 0·433689 : 1 : 0·57569,$$

and for the calculated and measured angles we have:

		Calc.	Meas.
$b \wedge k$,	$010 \wedge 021$	40° 58½′	41° 11′
$b \wedge e$,	$010 \wedge 111$	70° 53½′	70° 50′
$s \wedge s$,	$120 \wedge 1\bar{2}0$	81° 52′	82° 07′
$s \wedge e$,	$120 \wedge 111$	38° 19′	38° 19′, 38° 22′
$b \wedge s$,	$010 \wedge 120$	49° 04′	48° 30′
$e \wedge d$,	$111 \wedge 101$	19° 06½′	19° 08′, 19° 08′
$m \wedge m$	$110 \wedge 1\bar{1}0$	46° 53½′	47° 01′

Fracture conchoidal to splintery, brittle; H.=5. Sp. gr.= 3·108. From colorless to brownish white and light brown. Luster vitreous on the fracture, inclining to greasy on the crystal planes. Readily soluble in dilute acids, both before and after ignition. In a preliminary analysis in which the cleanest crystal fragments were examined, it was found that they contained some water, silica, ferrous oxide, manganous oxide, magnesia and lime, but were *entirely free* from phosphoric acid. As such fragments could not be obtained entirely free from calcite, a quantity of the calcite, enclosing monticellite, was crushed

* Pogg. Ann., 1871, Erg. Bd., v, 434.

fine enough to pass through a sieve of about fifty meshes to the inch, and separated by Thoulet's solution; afterwards the magnetite was taken out by a magnet and the resulting material, apparently pure, was analyzed. To my great surprise considerable quantities of phosphoric acid were found which was present as apatite, which by a closer microscopic examination of the original specimens could easily be distinguished.

The analyses gave:

		1.	2.
Ignition	=	2·28	2·29
SiO_2		33·47	33·46
Al_2O_3		0·16	0·19
MnO		1·11	1·13
FeO		5·09	4·93
MgO		20·71	20·52
CaO		35·18	35·31
P_2O_5		1·98	2·08
		99·98	99·91

Deducting the phosphoric acid as $Ca_5F(PO_4)_3$ (fluorapatite) in the first analysis 4·57 per cent, in the second 4·82 per cent of the same, gives the following as the composition of the pure Arkansas Monticellite:

		1.	Mol. ratio.		2.	Mol. ratio.	
Ignition	=	2·39	·133		2·41	·133	
SiO_2		35·08	·585		35·19	·586	
$Al_{23}O$		0·17	---		0·20	---	
MnO		1·16	·016		1·19	·016	
FeO		5·33	·074	·633	5·18	·072	·628
MgO		21·71	·543		21·58	·540	
CaO		34·16	·610		34·25	·611	
		100·00			100·00		

Leaving out the water, the molecular ratios of SiO_2:(Mg,Mn, Fe)O : CaO are:

in 1, ·585 : ·633 : ·610
in 2, ·586 : ·628 : ·611

corresponding to $(Mg,Mn,Fe)_2SiO_4 . Ca_2SiO_4$.

In both analyses the SiO_2 is a little short. As there is no sign of alteration and no lack of basic oxides, it is difficult to account for the presence of over 2 per cent of water, as the finely powdered mineral had been kept over sulphuric acid for several days before analyzing.

Chemical Laboratory, 111 S. 10th St., Philadelphia, Feb. 1, 1891.

ART. XLVI.—*Contributions to Mineralogy, No. 51;* by F. A. GENTH.

1. *Aguilarite*, a new species.

A PRECIOUS lot of about half a dozen specimens, secured by Mr. William Niven of Geo. L. English & Co., from Señor Aguilar, the superintendent of the San Carlos Mine at Guanajuato, Mexico, as Naumannite, were placed in my hands for identification. They all proved to be a new species which has been named *Aguilarite*, in acknowledgment to the discoverer of this interesting mineral. I am indebted to Messrs. Geo. L. English & Co. for allowing me to break off a sufficient quantity of this valuable material for investigation.

There was only *one piece* in the lot which gave aguilarite in a state of perfect purity. It is, associated with little quartz, imbedded in colorless calcite which was readily removed by dilute acetic acid. The pure crystals, thus obtained, were placed in the hands of Prof. S. L. Penfield, who very kindly determined the crystallization, of which he gives the following description:

"It is isometric; the crystals are skeleton dodecahedrons with only the edges well developed. Many are lengthened out in the direction of one of the crystallographic axes, looking then like a tetragonal prism, terminated by a pyramid of the opposite order; others are elongated in the direction of an octahedral axis and these resemble hexagonal prisms, terminated by a rhombohedron. I detached one crystal for measurement; it gave only approximate reflections; eight dodecahedral angles, in three different zones, gave angles which varied between 60° 33′ and 59° 35′, the average being 60° 5′, calculated 60° 0′. I also measured two angles over the top of the dodecahedron 89° 59′ and 90° 11′, calculated 90° 0′. The crystals are attached and grouped together, so that distinct, fully developed dodecahedrons do not seem to occur."

The largest crystals were not over $10^{mm} \times 6^{mm}$ in size, groups of crystals up to 15^{mm}. No cleavage observed; fracture hackly; sectile; malleable; H. = 2·5; sp. gr. = 7·586; color iron black; luster very brilliant. In an open tube at low heat, gradually increased to red heat, it yields metallic silver, a slight sublimate of selenium, slender silky needles of selenous oxide and sulphuric oxide, which latter, attacking silver, forms a small quantity of Ag_2SO_4; no SeO_3 could be observed. The analyses gave:

	1.	2.	Ratio.		Calculated.
Ag	79·13	79·07	·732	4	79·50
S	----	5·86	·183	1	5·89
Se	----	14·82	·188	1	14·61
		99·75			100·00

Represented by the formula : $Ag_2S + Ag_2Se$.

All the other specimens were more or less altered; the aguilarite crystals had become rounded, and in the proportion to the extent of the alteration, their crystalline form was more or less obliterated. They often were penetrated by round holes, showed the presence of metallic silver and were coated with microscopic iron-black crystals, sometimes in, apparently, hexagonal scales. Although this coating was quite brittle, I did not succeed in obtaining the unaltered nucleus of aguilarite in a state of purity, as has been proved by the following analyses :

	1.	2.	3.
Ag	78·09	77·85	75·75
S	not det.	7·55	8·32
Se	12·39	12·22	not det.

Sb, As, Cu, etc., not determined.

I was able to separate, in a state of approximate purity, a little over half a gram of the scaly brittle iron-black product of alteration, which gave :

		Ratio.			
Ag	67·08	·621		5·84	11·6
Cu	6·44	·101		0·94	2
Fe	0·82				
Sb	10·82	·090	·107	1·00	2
As	1·29	·017			
S	13·62	·426		3·98	8
	100·07				

Giving the molecular ratio of a cupriferous stephanite $5(Ag, Cu)_2S + (Sb, As)_2S_3$ with an admixture of metallic silver.

2. *Seleniferous Bismuthinite and Guanajuatite.*

A. *Seleniferous Bismuthinite.*—As crystallized Guanajuatite, Messrs. Geo. L. English & Co. sent me for identification a small specimen, consisting of slender, striated crystals, about 5^{mm} in length and 0·5 to 1^{mm} in thickness with distinct brachydiagonal cleavage, imbedded in indurated clay. Color light gray, some crystals showing a yellowish tarnish. Sp. gr. = 6·306. The analysis gave :

	1.	2.	Mean.	Ratio.		Calculated.
Bi	76·94	78·14	77·54	·371	10	77·08
S	14·15	13·96	14·06	·440	12	14·18
Se	8·80	not det.	8·80	·111	3	8·74
	99·89		100·40			100·00

This would prove the mineral to be a seleniferous bismuthinite of the composition $4Bi_2S_3+Bi_2Se_3$. A piece which I received about four years ago from Prof. Carlos F. de Landero of Guadalajara, Mex., more compact, but with slender crystals, imbedded in indurated clay, looks as if it had come from the same mass which furnished Messrs. Geo. L. English & Co.'s specimen.

B. *Guanajuatite or Frenzelite.*—The results under "A" suggested repeating the analysis of Guanajuatite with a specimen which came from an old German collection, purchased about ten years ago. It is compact, granular, indistinctly fibrous and of a light gray color. Spec. grav. = 6·977. The results of the analysis are as follows:

		Ratio.		Calculated.	Frenzel found.	
Bi	68·86	·330	6	68·74	Bi	67·38
S	4·68	·146	3	5·27	S	6·60
S	25·50	·320	6	25·99	Se	24·13
	99·04			100·00		

Corresponding to: $Bi_2S_3+2Bi_2Se_3$, analogous to the usual variety of tetradymite. The percentage of sulphur, in Frenzel's analysis, seems to be too high; as it is, the analysis would not lead to a rational formula, but the results are close enough to admit of a comparison with mine and suggest that the same mineral has been analyzed by both of us, and that the existence of the species cannot be questioned.

Chemical Laboratory, No. 111 S. 10th St., Philadelphia, March 23d, 1891.

Art. XLVII.—*Columbite of the Black Hills, South Dakota;* by Wm. P. Blake.

The publication of the paper on the columbite and tantalite of the Black Hills, of South Dakota, by Mr. W. P. Headden* is timely and important, particularly in giving for the first time a series of careful analyses of the mineral from the Etta Mine and from the Bob Ingersoll Claim, in comparison with

* This Journal, xli, 89, 1891.

the composition of the species from other localities. It is also agreeable to find that my original determination as columbite of the mineral from both the Etta and the Ingersoll was correct.*

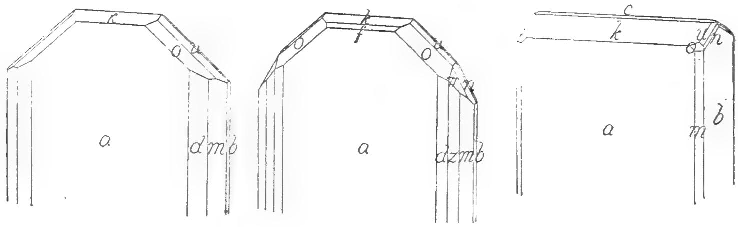
The specimens collected in 1884 have been carefully preserved with the intention of preparing a full description for publication so soon as the chemical investigation could be completed. As Mr. Headden's numerous analyses supply this want, it is now necessary only to present a few further notes and the results of a crystallographic study of the specimens, made at my request by Prof. S. L. Penfield, of the Sheffield Scientific School, and reported to me in April, 1890.

In breaking up the huge mass of columbite at the Ingersoll the only good crystalline terminations were those broken out from the quartz matrix. The mass when discovered by me did not show any crystallization which could have been used for the determination of its form. The exposed portions were rounded and weather worn. The blast which was intended to throw it out whole, if possible, disclosed the fact that it was made up largely of a series of broad plates interleaved in part by a translucent quartz. These plates are crystals flattened parallel to the macropinacoid a, 100, i-$\bar{\imath}$; some of them with bright crystal faces on the edges. The forms which were identified are as follows:

b, 010, i-$\breve{\imath}$	z, 530, i-$\bar{\frac{5}{3}}$	k, 103, $\frac{1}{3}$-$\bar{\imath}$	o, 111, 1	π, 121, 2-$\breve{2}$
m, 110, I	d, 730, i-$\bar{\frac{7}{3}}$	f, 102, $\frac{1}{2}$-$\bar{\imath}$	u, 133, 1-$\breve{3}$	n, 163, 2-$\breve{6}$

Fig. 1 represents the ordinary habit of the crystals while fig. 2 represents a more highly modified one which was observed. One small crystal had bright faces and gave on

1. 2. 3.



the goniometer fair reflections of the signal. Some of the principal measurements for the identification of the faces are given below, and for comparison the calculated angles obtained from the axial relation established by E. S. Dana,†
$\breve{a} : \bar{b} : \dot{c} = 0{\cdot}8285 : 1 : 0{\cdot}88976$

* This Journal, xxviii, 340, 1884. † Zeitschr. Kryst., xii, p. 266, 1886.

		Measured.	Calculated.
$m \wedge d$,	$110 \wedge 730$	20° 6′	20° $5\frac{1}{2}$′
$m \wedge z$,	$100 \wedge 530$	13 27	13 $12\frac{1}{2}$
$m \wedge m$,	$110 \wedge \bar{1}10$	100 39	100 43
$a \wedge f$,	$100 \wedge 102$	61 42	61 46
$a \wedge k$,	$100 \wedge 103$	70 30	70 18
$a \wedge o$,	$100 \wedge 111$	51 18	51 $15\frac{1}{2}$
$a \wedge u$,	$100 \wedge 133$	74 52	75 $1\frac{1}{2}$
$a \wedge n$,	$100 \wedge 163$	79 24	80 3
$a \wedge \pi$,	$100 \wedge 121$	62 14	62 15

The prism *d*, which is prominent on these crystals, is new to the species.

The crystals from the Etta Mine are to a great extent independently formed and are thicker and stouter than those from the Ingersoll. The largest crystal secured weighs several pounds, and measures about $1\frac{1}{2}$ inch by 5 inches and is $4\frac{1}{4}$ inches long; another is $1\frac{1}{2}\times3\times3\frac{1}{2}$; and a fragment of a larger crystal is 2 inches thick and 4 inches long. Most of them are detached from the gangue, or matrix, but one has portions of beryl and quartz adhering to the side.

The habit of the crystals is dependent upon a prominent development of the pinacoids *a*, 100, $i\text{-}\bar{\imath}$ and *b*, 010, $i\text{-}\breve{\imath}$ and the macrodome *k*, 103, $\frac{1}{3}\text{-}\bar{\imath}$. Other faces which were observed are *c*, 001, *O*; *m*, 110, *I*; *o*, 111, 1; *u*, 133, $1\text{-}\breve{3}$ and *n*, 163, $2\text{-}\breve{6}$. The arrangement of the planes is shown in fig. 3. The crystals were not suitable for accurate measurement; on the large crystals the forms were identified by means of a contact goniometer, and on a small crystal the following angles were measured on a reflecting goniometer:

		Measured.	Calculated.
$a \wedge k$,	$100 \wedge 103$	70°	70° 18′
$a \wedge m$,	$100 \wedge 110$	39 28′	39 $38\frac{1}{2}$
$a \wedge o$,	$100 \wedge 111$	51 20	51 $15\frac{1}{2}$
$b \wedge n$,	$010 \wedge 163$	29 15	30 50
$b \wedge u$,	$010 \wedge 133$	49 15	50 3

The specific gravity determinations invariably show that the Etta variety is the heavier of the two. The results upon different crystals and fragments were as follows:

From the Etta Mine.		From the Ingersoll Claim.	
6·580	6·642	5·873	5·881
6·610	(6·447 Penfield.)	5·879	(5·901 Penfield.)

A small tabular crystal found loose in the soil of Etta Hill gave me 6·171 and another from Spring Creek 6·132. Mr. Headden's determinations of the specific gravity of the Etta specimens range from 5·890 to 6·750, and for the Ingersoll specimen he found 5·901.

ART. XLVIII.—*The Raised Reefs of Fernando de Noronha;* by HENRY N. RIDLEY, M.A., F.L.S., Director of Gardens and Forests, Straits Settlements.

I HAVE recently received three numbers of this Journal (for February, March and April, 1889) in which are papers by Messrs. Branner and Williams on the Petrology and Mineralogy of Fernando de Noronha. I was one of the party sent out by the Royal Society of England and the British Museum, to explore this island not only mineralogically but botanically and zoologically in 1887. My companions were the Rev. T. S. Lea and Mr. G. Ramage. We explored the whole group and brought home upwards of 200 specimens of rocks and minerals, with sketches, plans and photographs of the more interesting geological bits. The minerals, which are now in the British Museum, were worked out by Mr. Davies of that establishment, and a short account was published in the Journal of the Linnean Society (Botanical Division) as an introduction to the natural history. These are, though much condensed as the Linnean Society does not as a rule publish petrographical papers, our views upon the structure and history of Fernando de Noronha, from its petrology. I hope Mr. Davies will publish further notes upon our rock-specimens, at fuller length. The results we arrived at as to the origin and history of the island differ a good deal from those of Messrs. Branner and Williams especially as to the relations of the phonolite and basalt and the rocks included by the latter under the name of æolian sandstones. It is about the latter I should like to speak as we carefully examined this rock in all parts of the islands and brought home specimens in all states of existence.

Briefly stated our theory was that this certainly rather variable rock, is what we have called reef rock, and is the same rock that is forming at different spots along the shores of Fernando de Noronha, of the Recife at Pernambuco and at Itamaraca in the same province.

This reef rock is full of corals, nullipores, broken shells, tests of echini, and at low water mark it is full of living organisms. Break into the interior it is more and more compact the nearer you go towards the shore, and eventually and at no great distance within the mass, you will see that the forms of its constituent animals are gone, and the whole is an amorphous mass of carbonate of lime, not as I shall show later, pure but mixed with mud in varying quantities. Owing to its irregular structure and growth it is soon worn into those curious shaped pinnacles and peaks that one sees often buried

in the guano of Ilha Rapta. In fact in many places one can easily trace the reef rock into these so-called æolian sandstone.

Mr. Branner (l. c. April, 1890, p. 249) gives the analysis of a piece of this rock which contains 92·27 per cent. of carbonate of lime, and only 2·20 p. c. silica. Again, on page 256, he gives two analyses, one of a piece of sandstone from Ilha Rapta, a clean and compact piece of one of the "tall jagged points left by the etching out of the surface by the combined action of rain water and ocean spray." This which would naturally have lost more of its soluble calcium carbonate than silica gives 98·33 per cent. calcium carbonate and ·09 per cent of silica and other matter insoluble in concentrated nitric acid! Can one call this sandstone at all?

I may here mention I have just returned from a short visit to Christmas island in the South Atlantic; an oceanic island, south of Java and in many points recalling Fernando de Noronha. It has a high ridge rising very straight out of very deep water, I am told there is a volcanic backbone to the island, and I found pebbles of tuffs and traps on the shore, but had no time to reach it. There are no sandy bays or dunes as in Fernando de Noronha. Here and there a little bay a few yards across has coral sand in it; but the whole of the island is covered with rock exactly like that of Ilha Rapta. Here and there are cliffs, layer over layer laid straight down, of this rock, just as at Fernando de Noronha. What force could have hurled sand dunes from an abysmal depth to the top of the lofty hill of Christmas island and where did the sand come from? Comminuted shells, coral dust, etc., form the softer bottom in many of these places, but sand is not plentiful, if it occurs at all.

But there are true æolian sandstones in Fernando de Noronha, on São José we found a block of real sandstone; nearly pure silica, apparently made of drift sand and very hard and compact. It contained a pseudomorph of a large crystal of feldspar in quartz and two or three shells (marine) well preserved. We were a little doubtful as to the position of this rock, as it was in the fort and might have been imported. But at Bahia San Antonio there were large sand dunes and æolian sandstone forming. In most spots it was feebly held together, in some more compact. The sand was being agglutinated by carbonate of lime, true, but whence was this carbonate of lime? of corals, nullipores, sea-shells? Certainly not. It was derived from innumerable shells of Helices and Bulimi. There was, except a stray shell here and there dropped by a sea bird, not a marine organism, giving up its carbonate of lime to form the sandstone. This true æolian sandstone was

very different in appearance and constituents from the reef-rock. I noted some points with respect to the reef-rocks. This rock is not at all like the coral reef of the open ocean atoll, such as Cocos island. It is not built to any large extent of the larger corals, but the nullipore seaweeds take the most important part, broken shells, echinus tests, worm tubes, crabs all go to make it up. The growth is chiefly produced by the nullipores. Now the reef does not occur everywhere. It cannot grow on sand because of the fluctuation of the bottom nor on bowlders which are too irregular and constantly shifting. In every spot, where I noticed reef in Fernando de Noronha, I found a small stream trickling into the sea, bringing down silt enough to make a firm bottom for the nullipores. The same observation was made at the Recife (I prefer to keep the old name for the reef itself) and at Itamaraca. And even here I see that where streams debouch into the sea the silty banks they form on one side are the best places for corals. This fact would account for not only all the silica which is deposited in the "reef rock," but for in some cases a larger proportion. If Mr. Branner will examine the Pernambuco Recife at low tide, he will see how compact it is and how it rings to the hammer. It contains much silt, but it is not an æolian sandstone, but true reef rock still growing. If he will walk along the coast to Olinda he will pass plenty of sand banks but though these have probably been growing for centuries there is not a bit of the rock which he classes as æolian sandstone, simply because no silt comes down, and the sand is too shifting for any growth of nullipores, etc.

I noticed too that where the base of the supposed sandstone could be seen it always overlay, neither sand, nor bowlders but silt. One spot at first puzzled me. It is in Ilha Rapta at the landing place, here is a stratum of black basalt bowlders which at one part is covered with about ten feet of reef rock. At first sight the reef appeared in contact with the bowlders, but closer examination showed that the bowlders had been cemented together (with gypsum probably) and then covered with silty stuff on which the reef had grown.

Both at Fernando de Noronha and at Christmas Island raised reefs occurred in strata lying flat upon each other. In some spots the upper part of each reef seemed distinct in texture and coloring, suggesting a frame before the deposit of the next reef upon it. I do not see how sand dunes could be formed into flat regular strata like this. When I was recently at Anjar point in Java opposite Krakatao I was shown an immense block of stone said to have been thrown there from the volcano. On close examination, however, it proved to be a block of coral-limestone, a block of reef rock, just like those

of Christmas Island, and Fernando de Noronha, in which one could hardly descry any definite remnants of its constituent animals. It had probably been hurled upon the shore by the frightful wave which at the eruption of Krakatao struck this coast with such violence and destroyed so many people. I shall as opportunity occurs examine the growth of reef-rock in these seas, but in conclusion I must say that I cannot at all see in Mr. Branner's paper enough evidence to support the theory that these rocks are æolian sandstones, while it appears to me certain that they are nothing more nor less than raised reefs of different ages.

NOTE.—Mr. Branner is quite correct in calling attention to the names given to various portions of the island by English and French travellers, which names are quite unknown to the natives. The map published by the Geographical Society from our plan contains most of those really known to the inhabitants. One or two spots which were absolutely unnamed we gave English names to. As to Ilha Rapta as I have called it in this paper in deference to Mr. Branner, all the inhabitants assured us that it was Ilha dos Rattos (i. e., Rattos pequenos), but it is likely enough it was originally called Ilha Rapta and the name was altered since.

ART. XLIX.—*The Cause of Active Compressive Stress in Rocks and Recent Rock Flexures;* by T. MELLARD READE, C.E., F.G.S., etc.

I HAVE read with much interest the account of a recent rock flexure on the lower Fox River about six miles northeast of Appleton, Wis., by Mr. Frank Cramer.* The rocks appear to have been in a state of stress from lateral pressure beyond anything that could possibly be due to gravitation and irregularity of the ground. This stress may have been and probably has been accumulating for a great length of time, the excavation described giving the needed release or in other words acting as the trigger that set off the gun.

If the effect of the small anticlinal ridge thrown up had not been to crack the walls of the paper mill and dislocate the machinery, the probability is that the movement would have gone unnoticed and it is most likely that such small readjustments of the earth's crust take place with greater frequency than is suspected. There is, however, one surface phenomenon which will tend to minimize accumulation of lateral pressure

* This Journal, March, 1890, pp. 220–225.

and that is the greater development of jointing in the surface rocks. Joints are widened by atmospheric agencies so that the surface rocks are frequently cut up into blocks not in actual contact. This is very noticeable in the sandstone quarries in Darley Dale, Derbyshire, where the joints are sometimes filled with infiltrated bowlder clay.

It is evident that if the surface rocks are not continuous over a considerable area the throwing up of the anticlinal ridge could not take place because there could be no accumulation of lateral stress.

There is no doubt that alternations of temperature take place in deep seated rocks, causing their bulk to undergo considerable variation. These rocks, owing to the pressure they are subjected to, are in absolute contact and form a homogeneous mass. I have attempted to show (Origin of Mountain Ranges, Chap. XXV), that the sudden release of these accumulated stresses, whether of tension or compression in deep seated rocks, is the cause of earthquakes that happen away from volcanic centers, and also that earthquakes are more frequent and greater in intensity in areas occupied by the newer rocks such as the Tertiary in all parts of the globe. It is in these areas that the greatest underground fluctuations of temperature occur in the crust of the earth. While my work was going through the press, the earthquake that ravaged Georgia and South Carolina, known as the Charleston earthquake, occurred on the night of August 31, 1886, thus emphasizing in an unfortunate way the principles I had expounded. The substratum here is of Tertiary rocks and the area was not recognized as one of great seismic activity. On the contrary an eminent geologist had only just before been insisting upon the great stability of the Atlantic borders of the North American continent.

These changes of temperature cannot, however, excepting in a secondary manner affect surface rocks, for they are kept by atmospheric influences at the mean temperature of the station at which they occur; we may therefore dismiss change of temperature of the surface rocks themselves as a *vera causa.*

The uplift on the Lower Fox River, though a striking example, can be paralleled by other instances of lateral pressure in surface rocks disclosed in the process of quarrying, suggesting a similar release of accumulated stress by unloading. Professor Kenny Hughes gives an instance (Geol. Mag., 1887, p. 511) of the bursting up of the floor of a limestone quarry at Dent Head and also of the floor of a tunnel at Ribble Head in Yorkshire, but he attributes these, whether rightly or not I am unable to say, to the fact that the beds rest on shale, inferring that the unequal pressure caused by the removal of part of the rock

forced up the shale as a viscous mass and so breaking the limestone bed above it.

It is evident, however, that this explanation will not meet the cases mentioned by Professor W. H. Niles where the phenomenon of lateral pressure he describes have acted over a considerable area and under diverse conditions of rock structure.*

At Monson, Mass., the quarry was in a belt of gneiss lying east of the red sandstone of the Connecticut Valley. The strike of the gneiss is north 10° east and the dip 10° north at the high angle of 80°. The pressure as seen by the movements of the beds in the quarry appears to have been parallel to the strike or at right angles to the movement that originally flexed the beds.

At Berea, Ohio, the quarries in which movement was observed are in sandstone (Berea grit of the Waverley group), lying nearly horizontal and the movement was in a north and south line.

At Lemont, Illinois, the quarries were in the Niagara limestone and an anticlinal axis was formed striking east and west 800 feet in length and rising from 6 to 8 inches in the most conspicuous parts. "It was formed along the line of vertical joint which extends beyond the limits of the quarry. The continuous edges of the bed were bent upward, making an elevation which was a little more upon the north side of the joint than upon the south and a slight fault was in this way produced." Another quarry referred to is at Waterford, Conn., in gneiss, and another quoted from Professor Johnston is in sandstone at Portland, Conn. Professor J. Johnston† says that these sandstone quarries are of great extent and 120 feet deep from the original surface of the ground. A groove about a foot wide and 80 feet long was being cut in a bed about 6 or 7 feet thick and in an east and west direction parallel to a natural joint. When the channel had been sunk to within about 9 inches of the bottom of the strata the remaining stone was crushed to fragments with a loud report and the walls of the groove had approached each other within about three-quarters of an inch. Other similar movements occur and these take place in a northerly and southerly direction and not in an easterly and westerly line.

In explanation of the Lower Fox River uplift, Mr. Cramer calls attention to the suggestion of Mr. Gilbert that such-like movements may have arisen from the expansion of the rocks

* The geologic agency of lateral pressure exhibited by certain movements of rocks. Proceedings of Boston Soc. of Nat. Hist., vol. xviii, 1876.

† Proc. of the American Assoc. for the Advancement of Science, Eighth Meeting, (1854).

consequent on a rise of temperature since the Glacial Period.* If the Glacial Period had been sufficiently prolonged to have affected the isogeotherms down to a considerable depth where the rocks are in tightly compressed contact, it is conceivable that the rise of temperature in the Post-glacial Period—again assuming a sufficient length of time has elapsed—may have been enough in some instances to create a low domical uplift, but it does not seem to me to be likely that the pressure from this cause could accumulate in surface rocks subject to atmospheric changes over such extended periods.

Before committing myself even to any suggested explanation of these extremely interesting phenomena I was desirous of ascertaining whether the districts described were affected by faulting, and if so to what extent and in which direction. Professor J. W. Spencer, who was staying with me at the time, kindly offered to make enquiries, but I am sorry to say the result has not been very encouraging, indeed very barren. As regards Ohio the State Geologist, Mr. Edward Orton, says that faults are exceedingly rare in Ohio geology but joints are finely shown at Berea; the master joints being a few degrees north of east and the main joints of all the Ohio rocks as far as he can recall the facts, except in one instance, have the same direction.

It appears to me that the cause of these active evidences of lateral pressure must be sought in the differential movements to which it is well known the crust of the earth is subjected. Since the Glacial period, in the British Isles, there are the strongest evidences of vertical movements both of subsidence and elevation having taken place. Having paid great attention both to Post-glacial and Glacial geology during the past twenty years I consider the evidences are overwhelming. Since the marine bowlder clay of the plains was laid down there have been two movements of elevation and two of depression to the extent of several hundred feet† but as the evidences of maximum movement are submerged we cannot estimate it. The well known sand and gravel glacial drift with shells on Moel Tryfan, North Wales, at an elevation of nearly 1400 feet above the sea has long been taken by most English Geologists as convincing evidence of a vertical movement of elevation to that extent since the beds were laid down and notwithstanding the views of some extreme glacialists I must be pardoned if I still consider them a monument of geologically recent elevation. It is true some of the American geolo-

* "Some Geologic Wrinkles," Proc. of American Assoc. for the Advancement of Science, Thirty-fifth Meeting, 1886.

† Geology and Physics of the Post Glacial Period, etc. Proc. Liverpool. Geol. Soc., Session 1871–2.

gists full of scientific enthusiasm have like the late Mr. Bell explained the Tryfan sands and gravels and in addition our bowlder clays as sea bottom pushed up by land ice ; but twenty years' careful work in the drift leads me to utterly disbelieve in the universality of this agency. Unless we are to throw on one side all the usual methods of geological investigation it were difficult to believe that current bedded and stratified sand and gravel full of shell fragments to all appearance exactly like a modern beach has been pushed up and landed on the top of a mountain spur—a spur of Snowdon in fact. If the inexorable logic of glacial events in America requires this interpretation I for one prefer to consider that there must be some great flaw in the premises.

Still whoever is right on this point, evidence has been accumulating rapidly on the American side of the Atlantic of glacial and post-glacial elevations and subsidences on a much more prodigious scale. According to Dr. George M. Dawson there have been orogenic disturbances both to the east and west preceding and during the Glacial period amounting to in one case not less than 3000 feet. Laurentian rocks derived from the east are found at elevations on the west amounting to in round figures 4000 feet and several thousand feet above their possible origin. He is of opinion that the subsidence of the Cordillera region of the west was accompanied by an elevation of the Laurentian highlands of the east. All these facts are set forth in his highly interesting presidential address to the Royal Society of Canada.*

The ancient beach lines of the Great Lakes as shown by Gilbert and Spencer evidence considerable differential vertical movements and the latter sees proof from buried river channels and other evidences that the American continent within geologically recent times stood several thousand feet higher than at present and more recently several hundred feet lower. The communication by Prof. J. D. Dana "On the Long Island Sound in the Quaternary Era† points also to considerable differential movements. Mr. Warren Upham has also enumerated a great many instances of Quaternary changes of level in a paper in the Geological Magazine.‡

The Pacific coast in California according to Prof. LeConte and Prof. Davidson of the U. S. Coast Survey give additional evidences of former elevation in the existence of subaqueous river channels as well as evidence of another character existing in some of the islands.

* Trans. of Royal Soc. of Canada, vol. viii, Sec. IV, 1890.
† This Journal, Dec., 1890, pp. 425–437.
‡ Quaternary Changes of Levels, Geol. Mag., Nov., 1890, pp. 492–497.

Taking then for granted the prevalence of these vertical movements in recent geologic times it is obvious that the subsidence of a low arch of elevation must tend to put the surface rocks into lateral compression. This will be largely governed no doubt by the existence or non-existence of faults and joints, and it is readily seen that when the strata are comparatively unbroken and continuous as in Ohio the most favorable conditions prevail. Doubtless the surface rocks adjust themselves to such movements by these anticlinals where they exist and minor subsidences may locally occur. In the Iroquois Beach the rising grade appears to be in a northeasterly direction and to vary from 1·60 feet to 6 feet per mile.*

Were this arch to subside to the horizontal it would be quite sufficient to develop considerable lateral pressure in the surface rocks. So long as the limit of elasticity of the rocks is not exceeded it is quite conceivable that the energy may have been stored up for a great length of time only wanting favorable conditions for its release.

It would take too long to discuss in one paper the cause of these differential vertical movements, but I would refer those interested to Chap. XXII of the Origin of Mountain Ranges where the larger bendings of the earth's crust are treated of. To call in the usual explanation of all lateral pressure phenomena, viz: tangential thrust arising from the shrinking of the earth's nucleus, is to call in an agency which were it the true one would have a more universal effect.

The fact that these conditions of active lateral pressure in surface rocks are recorded as unusual raises a strong presumption that tangential thrust is not the potent agent in geologic change that some maintain, for were it so most of the surface crust would on artificial penetration exhibit powerful signs of pent up energy, for it was clearly proved by me in 1886 and shortly afterwards independently by Mr. Davison that in a cooling solid globe *the greatest compression takes place on the surface* and the same reasoning applies as I have shown in the same work to a globe with a hard crust of the requisite thickness even if the nucleus be molten.

Park Corners, Liverpool, England,
Jan. 2, 1891.

* The Deformation of the Iroquois Beach, by Dr. J. W. Spencer. This Journal, Dec., 1890, p. 447.

ART. L.—*A new Phosphate from the Black Hills of South Dakota;* by W. P. HEADDEN.

THE mineral described in this note was found in the Nimrod, now called the Riverton, lode, near Harney City, Pennington Co., South Dakota. It occurs in the granite common to the district, in kidney-shaped masses, some of them weighing upwards of fifty pounds, but they are not numerous. Externally they are dark brown, due to oxidation which has taken place, in some cases, to the depth of a quarter of an inch, in others only on the surface. These masses enclose a few crystals of white mica, but are not penetrated by crystals of this mineral which often adhere to the surface. Some of them show small seams of an almost white mineral with two cleavages nearly at right angles to one another; its composition has not been determined. It is easily recognized under the microscope, especially in polarized light upon which it acts strongly, while the inclosing mineral has no effect upon it. In places there are dark patches visible only in pieces thin enough to transmit light. The mineral is amorphous and by reflected light has a dark brown color; by transmitted light in very thin pieces it is a yellowish brown, in thicker ones a brown color. It has a resinous-vitreous lustre, an uneven to conchoidal fracture and no cleavage. In thin flakes it is translucent to transparent. Specific gravity, 3-401; hardness, 5·5 and is brittle. It is readily soluble in acids, fuses easily in the flame of a candle and reacts for manganese, iron and soda, before the blowpipe.

The material for analysis was carefully selected, only such pieces being taken as were thin enough to show by transmitted light that they were free from the dark patches and macroscopic seams. The results were as follows:

	I.	II.	III.	IV.	V.	Mean.	Oxygen.		
P_2O_5	38·61	38·22	38·45	38·49	38·86	38·52	·217	2·17—	1
MnO	29·74	29·74	28·97	30·08	----	29·64	·0668		
CaO	7·70	7·66	7·66	7·08	7·28	7·47	·0213		
Al_2O_3	9·94	10·34	10·09	----	10·14	10·13	·0472		
FeO	3·83	4·14	4·01	4·00	----	4·00	·0089		
MgO	0·14	----	0·16	----	----	0·15	·0006	1·977	0·91
Na_2O	5·52	----	5·70	5·68	----	5·52	·0142		
K_2O	0·30	----			----	0·30	·0005		
Li_2O	trace	----	trace	----	----	trace			
H_2O	4·15	----	4·43	----	----	4·29	·0382		
Cl	0·11	----	not det.	----	----	0·11			
F	trace	----	---	----	----	trace			
Insol.	0·14	----	0·18	----	----	0·16			
	100·18		99·65			100·29			

This ratio approaches 1 : 1 and includes the water as basic and the whole of the iron as FeO. If the water be considered as water of hydration, the oxygen-relations cannot be expressed by any simple ratio. If instead of computing the oxygen alone we reckon the atomic equivalents we obtain as favorable a ratio; for, substituting an equivalent number of bivalent atoms for Al_2^{vi} we obtain for the ratio of $P : \overset{II}{R} : O = 1 : 2{\cdot}49 : 5{\cdot}18$ instead of $1 : 2{\cdot}5 : 5$ or $2 : 5 : 10$ corresponding to the formula $P_2\overset{I}{R}_5O_{10}$ which is a salt corresponding to the normal phosphoric acid H_5PO_5 and in which $R = (MnCaFeH_2Na_2)\frac{3}{4} + Al\frac{1}{4}$. Other complete analyses, than those given were made of less carefully selected material with closely agreeing results.

I would propose to call this new phosphate Griphite, from γριφος *puzzle*, in allusion to its unusual and somewhat enigmatical composition.

A Phosphate near Triphylite from the Black Hills.

A mineral, associated with beryl and spodumene, occurs in nodules in the granite of the Nickel Plate tin claim, Pennington Co., South Dakota. The inner portions of these nodules are nearly free from other minerals while the outer portions contain some small bunches of mica, a few isolated, black, prismatic crystals, which are brown by transmitted light, and here and there small patches of a light brown mineral with resinous luster, conchoidal fracture and one distinct cleavage. Neither the black crystal nor the light brown masses seem to be derived by decomposition, from the surrounding mass as it is wholly unaltered.*

The mineral forming these nodules, is, in the mass, dark green, in thin splinters, it is translucent to transparent and is a light yellowish green; it fuses easily on the edges of thin pieces in the flame of a candle, to a dark brown, magnetic globule and colors the blowpipe flame a faint yellow. It has a hardness of about 5, a specific gravity of 3·612; cleavage in two directions, in one it is perfect in the other it is quite imperfect and the directions are not at right angles to each other. The lustre is vitreous and the fracture uneven to small conchoidal; streak and powder very light green, almost white. When exposed to the atmosphere for a short time it darkens externally due to oxidation. The freshest material was taken for analysis which gave the following results:

* Subsequent examination showed the black prismatic crystals to be crystals of cassiterite with the usual combination of the pyramid and prism, the prism being very strongly developed. Many of these crystals are fretted to such an extent that they form almost skeleton crystals.

	I.	II.	Mean.		At. Eq.		
P_2O_5	38·52	38·76	38·64		54·16	54·66	1
FeO	25·29	24·82	25·05		34·78		
MnO	15·45	15·64	15·54		17·40		
CaO	5·42	5·64	5·53		9·87		
MgO	1·56	1·44	1·50		4·00	81·20	1·5
Na_2O	7·46	(7·46)	7·46	(R_2)	12·02		
K_2O	2·00	(2·00)	2·00	"	2·12		
Li_2O	(·28)	·28	·28	"	1·00		
F	·69	(0 69)	·69	oxygen			
Ignition	·73	(0·73)	·73		223·	223·00	4·09
Gangue	2·49	2 44	2·47				
	99·89	99·88	99·89				

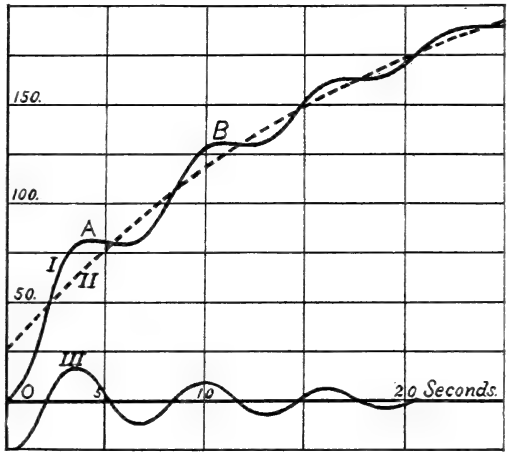
This ratio 1 : 1·5 : 4·09 or 2 : 3 : 8 indicates $\overset{\text{II}}{R}_3P_2O_8$ as the formula for the mineral in which the ratio of $\overset{\text{I}}{R}_2 : \overset{\text{II}}{R}$ is 1 : 4·4 or 2 : 9 giving as molecular formula $2(\overset{\text{I}}{R}_2)_3P_2O_8+9\overset{\text{II}}{R}_3P_2O_8$ or better $4\overset{\text{I}}{R}_3PO_4+9\overset{\text{II}}{R}_3P_2O_8$. The ratio of $\overset{\text{I}}{R}_3PO_4$ to $\overset{\text{II}}{R}_3P_2O_8$ in triphylite is 1 : 1 but here it is 1 : 2¼, too wide a deviation to admit of their being regarded as identical.

ART. LI.—*Note on Certain Peculiarities in the Behavior of a Galvanometer when used with the Thermopile;* by ERNEST MERRITT, M.E.

(Contributions from the Physical Laboratory of Cornell University, No. 8.)

WHEN a galvanometer, whose needle is not too thoroughly damped, is used in connection with a thermopile, a curious phenomenon is observed. On suddenly exposing one face of the pile to some source of radiant heat, the needle of the galvanometer moves quickly to one side. In a short time, however, the motion becomes less rapid, and in the course of a few seconds the needle comes to rest, and in many cases moves backward for a short distance. This behavior is then repeated, and it is only after a long series of such throws, which gradually become less and less marked, that the final steady deflection is reached. The curve OAB in fig. 1 represents graphically this peculiar motion as observed in the case of a Thomson tripod galvanometer, the abscissa of any point on the curve showing the time that has elapsed since the beginning of the motion, and the corresponding ordinate being proportional to the deflection of the needle from its position of rest. With a galvanometer whose needle is more nearly "dead beat" the maxima and minima which are so clearly shown in the figure, may not be present; but the general form of the curve will still be the same.

The effect described above was noticed in 1884 by Violle * while using a thermopile to investigate the radiation of molten



platinum and silver. Numerous observations of successive maxima and minima are given in his paper; but no explanation of the phenomenon is offered. Messrs. Rubens and Ritter have observed a similar phenomenon with a peculiar form of bolometer which they used for quantitative measurements of electromagnetic waves; † and numerous experiments that have been made in the laboratory of Cornell University with a bolometer of the ordinary type, and with a number of different galvanometers and thermopiles, seem to show that this behavior is not peculiar to any one instrument, but is always observed when a bolometer or thermopile, in circuit with a galvanometer, is *suddenly* exposed to radiant heat. My attention was first called to the phenomenon in 1888, while engaged in an investigation of the energy of the light from incandescent lamps. In a paper‡ published during the following year I called attention to the fact, which at that time rested only upon experimental grounds, that the first throw of the needle, under the circumstances described above, bears a constant ratio to the final deflection, this ratio being independent of the intensity of the radiation to which the pile is exposed.

* "Sur l'etalon absolu de la lumière." Annales de Chimie et de Physique, VI, iii, p. 373.

† "Bemerkung zu den Hertz'schen Versuchen über Strahlen electrischer Kraft," Wied. Ann., vol. xl, p. 63.

‡ "Some Determinations of the Energy of the Light from Incandescent Lamps," this Journal, vol. xxxvii, p. 167.

The phenomenon appears to be due to the inertia of the galvanometer needle, and to the fact that a considerable time elapses after the pile has been exposed to a source of heat, before a constant temperature is reached. On account of its inertia the needle is unable to follow immediately the rapidly increasing current that flows when the face of the pile is first exposed. In a short time, however, the continued action of the deflecting force imparts sufficient velocity to carry it not merely to the position which corresponds to the current then flowing, but to a considerable distance beyond this point. The result is that the motion of the needle is stopped, and a retrograde movement begins, which continues until the pile has been heated sufficiently to cause another throw forward. This behavior is then repeated until the temperature of the pile has become constant, or until the oscillatory motion of the needle has been destroyed by damping. If it be assumed that the heating of the pile takes place in accordance with Newton's Law of Cooling, and that the electromotive force of the pile, throughout the small range of temperatures with which we have to deal, is proportional to the difference in temperature between the junctions, the equation of motion of the needle may be derived as follows:

Let T_0 be the final difference in temperature between the two faces of the pile, and T the difference at any time t. Then the current in the galvanometer is given by the equation:

$$i = \frac{E}{R} = \frac{PT}{R} = \frac{PT_0}{R}\left(1 - \varepsilon^{-kt}\right) \qquad (1$$

k being the radiation constant of the surface of the pile, and P the electromotive force developed by a difference in temperature of one degree between the two junctions.

The couple due to the action of this current upon the needle, and tending to deflect it, is $K\, i m\, l \cos\theta$, θ being the deflection, and K a constant depending on the form and dimensions of the galvanometer. Since θ is always small, $\cos\theta$ will never differ appreciably from unity. If, therefore, we substitute for i its value as given in (1) and replace $\frac{K\, m\, l\, P}{R}$ by Q, the expression for the deflecting couple is reduced to $QT_0\,(1-\varepsilon^{-kt})$. The only other forces that act upon the needle are the return force of the earth's field, which for small deflections is equal to $N\theta$, and the retarding effect of damping. The latter force being proportional to the velocity of the needle, may be represented by $L\,\frac{d\theta}{dt}$. These three forces may now be equated to the product of the moment of inertia of the

needle into its angular acceleration, and thus lead to the following equation of motion:

$$M\rho^2 \frac{d^2\theta}{dt^2} + L\frac{d\theta}{dt} + N\theta = QT_0\,(1-\varepsilon^{-kt}) \tag{2}$$

The solution of this equation consists of two parts: (1) the general solution of the "complementary equation" obtained by equating the left hand member to zero; (2) a special solution of the complete equation. The first is readily seen to be the ordinary expression for the motion of a damped needle:

$$\theta = C\varepsilon^{-ht}\cos\left(\frac{2\pi t}{\tau} + \varphi\right) \tag{3}$$

while an easy application of the symbolic method to the complete equation gives the following special solution:

$$\theta = \frac{Q\,T_0}{N} - \frac{QT_0}{M\rho^2 k^2 - L\,k + N}\,\varepsilon^{-kt}. \tag{4}$$

The complete solution of (2) is the sum of these two parts, and when simplified by the substitution of single letters for the complex coefficients that arise during the integration, gives the following expression for θ:

$$\theta = C\,\varepsilon^{-ht}\cos\left(\frac{2\pi t}{\tau} + \varphi\right) - m\,T_0\,\varepsilon^{-kt} + l\,T_0. \tag{5}$$

The two constants of integration C and φ are determined from the consideration that when t is equal to zero, both θ and $\frac{d\theta}{dt}$ are also zero.

$$C = \frac{\tau}{2\pi}T_0\left\{[m(k-h) + lh]^2 + \frac{4\pi^2}{\tau^2}(m-l)^2\right\}^{\frac{1}{2}}.$$

$$\cos\varphi = \frac{l-m}{C}\,.\,T_0 = \frac{l-m}{C'}\,.$$

It will be observed that all the coefficients in (5) contain T_0 as a factor, while φ is independent of T_0. The equation may therefore be written:

$$\theta = T_0\left[C'\,\varepsilon^{-ht}\cos\left(\frac{2\pi t}{\tau} + \varphi\right) - m\,\varepsilon^{-kt} + l.\right] \tag{6}$$

The motion represented by this equation evidently possesses all the characteristics of that shown in fig. 1. It may be looked upon as resulting from the combination of two motions, one of them being a steady increase of deflection in accordance with the logarithmic curve represented by the last two terms of the equation, the other a motion of oscillation with grad-

ually diminishing amplitude, as indicated by the first term. Evidently τ is the period of vibration of the needle, and $\frac{h\tau}{2}$ its logarithmic decrement.

To test the above equation a series of observations was made with a Thomson tripod galvanometer, every precaution being taken to secure a constant source of heat, and to avoid errors due to draughts of air, magnetic disturbances, etc. The period of vibration of the needle, and its logarithmic decrement (with the thermopile in circuit) were first determined by the ordinary methods. Data for the curve shown in the figure were then obtained by recording on a chronograph the times of the successive maxima and minima, and the time at which the needle passed each tenth division of the scale. Assuming that the equation derived above truly represented the motion, I then attempted to analyze the curve into its two components, and after a few trials obtained the curves II and III of fig. 1. These two, when combined, give exactly the motion that was observed, while both are capable of being quite accurately represented by equations of the form indicated in (6). For example curve II was found to agree closely with the equation:

$$\theta' = 310 - 283\,\varepsilon^{-0{,}037t} \qquad (7$$

the differences between observed and computed values of θ' in no case exceeding two per cent. The time of vibration of the needle, as computed from curve III, was found to be 6·1 seconds, while that observed when the needle was allowed to swing freely, was 6·0 seconds. The observed and computed values of the ratio of damping show a similar close agreement, being equal to 1·28 and 1·31 respectively.

The fact, which has already been mentioned, that the first throw of the needle bears a constant ratio to the final deflection, is confirmed by equation (6). Since T_0 is a factor of the right hand member of the equation, and since the expression inside the bracket is independent of T_0, the only effect of a change in the intensity of the source of heat would be to increase or diminish all the ordinates of curve I in the same proportion, the ratio of any two ordinates remaining the same. If, therefore, the final deflection of the needle is proportional to the quantity of heat received by the pile, the first throw will also be proportional to this quantity, and may in all cases be used instead of the final deflection. Experiments made in 1888 to test the above conclusion showed the ratio to be constant for deflections ranging from 100^{mm} to 20^{mm}, but for smaller deflections there was apparently a deviation from the law. I have therefore repeated the observations, using great

care to avoid as far as possible all sources of error, and obtain the following results as the mean of a number of measurements:

First throw.	Final deflection.	Ratio.
53·0 mm.	196·0 mm.	0·270
36·5	136·7	0 265
17·75	65·0	0·273
5 25	19·75	0·265

The slight irregular variations which occur might easily be accounted for by the unavoidable errors of observation, especially as the source of heat, an Argand burner, could not be relied upon as perfectly constant. The conclusion that the ratio is independent of the deflection, seems therefore to be justified, at least in the case of the galvanometer used in these experiments.

The importance of this conclusion will readily be seen by those who have had occasion to use a thermopile for accurate measurements of radiant heat. Draughts of air, and other almost unavoidable sources of temperature variation, frequently make the galvanometer quite unsteady, while the extreme delicacy of the instruments that must be used in work of this kind renders them especially susceptible to magnetic disturbances. Many observations are thus made valueless by a change in the zero point of the galvanometer during the three or four minutes required for the needle to come to rest. Only a few seconds are required, however, for the first throw of the needle, and the change in zero point during this time would scarcely ever be sufficient to cause an appreciable error. The use of the first throw in place of the final deflection may therefore lead to greater accuracy as well as to a saving of time.

It will be observed that the principle underlying this method of taking readings is not confined to the case of the thermopile, but is capable of quite wide application. The following are suggested as cases in which the method may be employed with especial advantage:

(1) All ordinary measurements of radiant heat, when the conditions are such as to make the galvanometer unsteady, or when the saving of time is a consideration.

(2) For purposes of demonstration in the lecture room. A number of experiments which are usually considered unavailable for lecture demonstrations have been quickly and accurately performed in this way under conditions that would render the use of the ordinary method entirely out of the question.

(3) For measurements of the heat from a variable source. The first throw of the needle will in this case give the amount of radiant energy at the very instant of exposing the pile.

(4) For work with a bolometer or similar instrument, under the same conditions that apply in the case of the thermopile.

(5) For the measurement of a constant or variable current, where it is desirable for any reason to take readings quickly. For example, the initial value of the current from a cell which is subject to rapid polarization may be determined by the first throw of the needle.

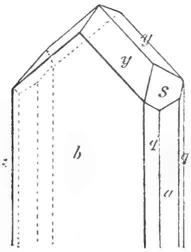
Other applications of the method will doubtless suggest themselves. It is with the hope that a phenomenon which at first appears to be merely a matter of curiosity, may thus be made of practical value in the laboratory, that this note is presented.

ART. LII.—*Supplementary Notice on the Polycrase of North and South Carolina;* by W. E. HIDDEN and J. B. MACKINTOSH.

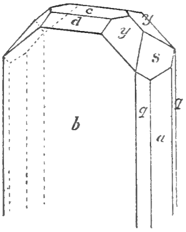
THE occurrence and composition of this mineral were partially announced by us in volume xxxix, pp. 302–306, of this Journal (June, 1890), and the localities have received no development of moment since that publication.

The South Carolina locality is distant about four miles from Marietta, in Greenville County, and is situated otherwise as before described. As to the form of the mineral, we have some interesting features to add to our previous statements and we here subjoin two figures (1 and 2) representing the

1.



2.



two types observed and a corrected list of occurring planes with the angles obtained by using a contact goniometer. The planes observed are as follows, those marked with an asterisk (*) are new:

a (010, *i*-ĭ)	*d* (103, $\frac{1}{3}$-ī)*	*y* (133, 1-3̆)
b (100, *i*-ī)	*u* (011, 1-ĭ)	*z* (233, 1-$\breve{\frac{3}{2}}$)*
c (001, O)*	*s* (021, 2-ĭ)	*q* (130, *i*-3̆)

Angles (approx.) observed:

$a \wedge s = 151\frac{1}{2}°$	$b \wedge d = 107\frac{1}{2}°$	$b \wedge z = 117\frac{1}{2}°$
$u \wedge u \quad 94°$	$b \wedge y \quad 104°$	$z \wedge y \quad 140°$
$a \wedge q \quad 160°$		

These angles closely agree with those recorded for polycrase in Dana's System of Min., p. 523.

Among the South Carolina crystals we observed several apparent twins, one was parallel to *s* (021, 2-$\breve{i}$) and another seemingly parallel to *d* (103, $\frac{1}{3}$-$\bar{i}$). Among the North Carolina crystals one was found quite perfectly twinned parallel to *u* (011, 1-$\breve{i}$). Whenever one of the South Carolina crystals was found terminated at both ends, it was discovered to be hemimorphic in the occurrence of the planes *c* (001, *O*) and *d* (103, $\frac{1}{3}$-$\bar{i}$) and invariably *hemihedral* as to the plane *z* (223, 1-$\frac{3}{2}$); these two features being new to the species.

Figures 1 and 2 were, in several instances, combined in the same crystal; though no crystals were found that had both terminations perfect. Most of the specimens were fragmentary and no crystals or masses were found attached to a matrix. It seems that the one and a quarter kilograms received by us was obtained by washing after the manner of gold mining some kaolinized coarse granite and that this quantity represents nine-tenths of the total amount found at the Marietta, South Carolina, locality (not ten kilos [22 lbs.] as before stated).

Concerning the Henderson county, North Carolina, locality nothing noteworthy has been found there recently.

Our later attempts in the separation of the metallic acids have been somewhat more satisfactory and acting upon a suggestion made to us by Dr. F. A. Genth we made the initial fusion with potassium bi-sulphate (we had previously used the sodium salt). Our results have enabled us to positively identify this mineral as polycrase and to arrive at a very satisfactory formula for the species.

The corrected analyses of two varieties are as follows:—

	Henderson Co., N. C.		Oxygen ratio.		Greenville Co., S. C.		Oxygen ratio.	
Cb_2O_5	19·48	----	36·35	5·000	19·37	----	36·14	5·000
TiO_2	29·31	----	73·27	10·078	28·51	----	71·27	9·858
Y_2O_3, etc.	27·55*	30·39			21·23†	23·06		
FeO	2·87	4·00	48·73	6·703	2·47	3·43		
UO_3	13·77	14·34			19·47	20·35	48·58	6·719
PbO	----	----	----		0·46	0·20		
Fe_2O_3	----	----	----		0·18	0·33		
CaO	----	----	----		0·68	1·21		
H_2O	5·18	----	28·83	3·965	4·46	----	24·78	3·427
Insol.	----	----	----		0·12			
SiO_2	----	----	----		1·01			
	98·16%				97·96%			

* At. w't. = 112. † At. w't. = 114·1

Inspection of the oxygen ratios shows that when reduced to the simplest terms the relation is, as follows, $Cb_2O_5 : TiO_2 : RO : H_2O = 1 : 2 : 1\frac{1}{3} : \frac{2}{3}$, there being in both cases a slight excess of water which undoubtedly does not enter into the composition of the mineral. The formula which we deduce for the species is therefore $3(Cb_2O_5, 5TiO_2)\ 10(2RO+H_2O)$ or grouping H_2O under the general head of RO we have the simple form Cb_2O_5, 5 TiO_2, 10RO. It is evident that this is not merely an isomorphous mixture of a columbate and a titanate, but that we have a definite salt of a complex inorganic acid, a columbo-titanate properly so-called. It seems also that we are justified in regarding water as an essential constituent. The separation of the metallic acids is even yet not very satisfactory, as our titanic acid shows the presence of columbic acid, but we feel assured that the formula deduced will not be altered by the results of more exact separations.

Regarding the yttria earths present in both varieties we would state that a concentrated solution of them exhibited little if any absorption spectrum and the ignited oxides were of a paler straw color than any we have yet met with, approaching nearly to whiteness in the Marietta mineral.

Prof. Rowland has kindly examined the South Carolina variety spectroscopically in its crude condition, and has identified all the lines of its spectrum, except one or two, as belonging to

Nb, Ti, Yt earths, Sc, Ur, Fe, Pb.

Faint evidences also of Mn, Al, Neo, Di, La, Th (?) and Ce, with the lines of Nb very weak. "There was no Praseo, Di, Ta, Be, Tl or Ge."

He adds that "he has not tried to identify other elements as all the portion of the spectrum examined [i. e. 2 feet out of 10] was satisfied by the above mentioned. The amount of thorium was too minute to be certain of. There was more scandium than in any other mineral he had ever studied spectrographically, except xenotime (from North Carolina) and one exceptional mass of samarskite."

The discovery, by Prof. Rowland, of the presence of scandium in this polycrase adds very materially to its interest.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *On the Speed of Chemical Reactions in Jelly.*—Since the liquid condition of substances is generally regarded as essential to the rapid and uniform progress of chemical changes, Reform-

ATSKY has considered it desirable to test the question whether in the case of slow reactions, the speed is influenced by the passage of the medium into the semi-solid state, like a jelly. For this purpose he selected the katalysis of methyl acetate by hydrochloric acid. Two solutions were prepared: one containing 20 c. c. half-normal hydrochloric acid, with 10 c. c. of water and one c. c. methyl acetate; the other 20 c. c. of the same acid, with 10 c. c. agar-agar solution of 1·25 per cent, and 1 c. c. methyl acetate. These solutions were placed in separate vessels and the temperature regulated by a thermostat to 25°. The strength of the agar-agar solution was so regulated, that at 35° the mixture was completely liquid, while at 25° it was so solid that the vessel could be inverted without showing more than traces of flowing. At the same time, the jelly had so little coherence that it could be drawn into a pipette with a somewhat large opening and could be so far divided by stirring with a glass rod as to permit of titration. Two parallel sets of experiments were made, the c. c. of baryta water required to neutralize the acid in one c. c. of the solution being noted at equal intervals for each solution. The numbers given in the paper show that in both cases the speed of the reaction is the same, within the errors of experiment. This result indeed might have been expected. The speed of chemical changes in homogeneous systems depends not on the greater or less speed of the final masses with regard to each other, but upon that of the molecular motion; so that it is a function not of the interior friction, but of the diffusion-coefficient. Since therefore it has been proved that the speed of diffusion in agar-jelly is the same as in pure water, it follows that the speed of chemical change cannot be materially altered by the presence of the jelly. Still it was important to establish this result by direct experiment.—*Zeitschr. physikal. Chem.*, vii, 34, Jan., 1891. G. F. B.

2. *On the Direct-reading of Volumes in Vapor-density Determinations.*—LUNGE and NEUBERG have applied the apparatus, contrived by the former chemist for the direct reading of gas volumes,* to the determination of vapor-densities. For this purpose they attach the Meyer bulb to the measuring tube in place of the gas evolution flask. After the vapor in the bulb has expelled the corresponding volume of air, the pressure tube is raised until the level of the mercury in the reduction tube reaches the normal mark. Since under these conditions the gas-volume is also at the normal pressure and temperature, this volume may be directly read off. If this reading is in cubic centimeters, g grams of the substance give v cubic centimeters of vapor, and the density $D=g/v.\ 0{\cdot}001293$. By this method the vapor density of benzene was determined as 2·66 – 2·76, that of naphthalene 4·2, that of triphenyl-methane 8·24, and that of mercury 6·8. In all these cases except the first, the temperature of determination was below the boiling point of the substance; the value of mercury for example being obtained in the vapor of diphenyl at 254°, the

* This Journal, III, xxxix, 396, May, 1890.

boiling point of mercury itself being 359.—*Ber. Berl. Chem. Ges.*, xxiv, 729, March, 1891. G. F. B.

3. *On Hydrazoic Acid.*—Further observations upon azoimide or hydrazoic acid N_3H, have been published by CURTIUS in connection with RADENHAUSEN. They have succeeded in isolating the anhydrous gas in the pure state and find that it is permanent only at temperatures above 37°. Below this even at the atmospheric pressure it condenses to a clear colorless mobile liquid, which is highly explosive, and which possesses the intolerable odor of the gas. The liquid is readily miscible with water or alcohol. On fractionating the concentrated aqueous solution four times, an acid was obtained containing over 90 per cent of N_3H. From this the last traces of water were removed by means of fused calcium chloride. The anhydrous liquid thus obtained is found to boil at 37°. When suddenly heated, it explodes with extraordinary violence with a vivid blue flame. In a Torricellian vacuum it explodes spontaneously at the ordinary temperature; the explosion under these circumstances of only five centigrams being sufficient to pulverize the apparatus completely, driving the mercury in the form of dust into every corner of a large laboratory. On one occasion, about 0·7 gram suddenly exploded on removing the tube containing it from a freezing mixture in which it had been immersed. Every glass vessel in the vicinity was completely shattered by the concussion and one of the authors was seriously injured. By determinations of its conductivity, Ostwald finds this acid to be a little stronger than acetic acid. Moreover, the authors have not succeeded in effecting the change of the ammonium salt N_3NH_4 into an isomeric substance, as suggested by Mendeléef. The ammonium salt itself crystallizes in fine large prisms, which grow continually smaller and finally disappear, by continuous sublimation.—*Nature*, xliii, 378, Feb. 1891. G. F. B.

4. *On the Production of Arabinose from Wheat bran.*—STEIGER and SCHULZE have shown that, when wheat bran, freed from starch and albuminous matter, is boiled for several hours with a three per cent sulphuric acid, the acid removed by barium carbonate, the solution filtered, evaporated and extracted with alcohol, there crystallizes out arabinose on evaporation of the alcohol. It is probably formed by the hydrolysis of metaraban, a constituent of the cell membrane which cannot be obtained pure but which gives a cherry-red color on warming with hydrochloric acid and phloroglucinol.—*Ber. Berl. Chem. Ges.*, xxiii, 3110, October, 1890. G. F. B.

5. *On distinguishing Arsenic from Antimony.*—DENIGÈS proposes to distinguish between the deposits of arsenic and antimony by the fact that if the stain obtained by Marsh's test is placed in a porcelain capsule and heated with a few drops of pure nitric acid, and then treated with a small quantity of ammonium molybdate dissolved in nitric acid, the antimony deposit gives no precipitate while arsenic forms arseno-molybdic acid which separates

as a yellow precipitate. This under the microscope is seen to consist of stellate crystals with triangular arms, generally six, arranged in rectangular planes along the axes of a cube, and which polarize light. The author regards this as the most sensitive and distinctive test for arsenic. He prepares the ammonium molybdate solution by dissolving ten grams of this salt and 25 grams of ammonium nitrate in 100 c. c. of warm water. After cooling, 100 c. c. of pure nitric acid of sp. gr. 1·20 are added drop by drop with active stirring. Then the liquid is heated on the water bath for ten minutes, allowed to cool and after 48 hours, filtered.—*C. R.*, cxi, 824; *J. Chem. Soc.*, lx, 364, March, 1891.

G. F. B.

6. *On Priestley's Eudiometric method.*—The method adopted by Priestley for measuring the oxygen in the air by mixing a measured volume of nitrogen dioxide with it and noting the diminution of volume, has been condemned as inaccurate. WANKLYN has investigated the matter and concludes that the inaccuracy is due to the oxygen present in the water through which the gas is made to pass. This source of inaccuracy may be avoided by using a Hempel apparatus and measuring the air in the gas burette and then passing it into an absorption pipette containing water. The nitrogen dioxide is introduced into the gas burette and measured and then (without bubbling through water) passed into the air in the absorption pipette. After the nitric tetroxide formed has been absorbed by the water in the absorption pipette the gas is passed back into the gas pipette and is again measured.—*J. Chem. Soc.*, lx, 362, March, 1891. G. F. B.

7. *On Crystalline Liquids.*—Attention has been drawn by LEHMANN to the fact that the optical behavior of certain liquids is such as to suggest a crystalline structure in them. Chemically however these liquids are homogeneous and their anisotropic character is not due to external stress. He now raises the question whether liquids which are isotropic are non-crystalline, or whether they are crystalline and isometric. In view of the free miscibility of liquids, however, he concludes that they are non-crystalline, since were this not the case they could mix only with isomorphous substances. This conclusion the author supports by experiments on the miscibility of crystalline liquids with each other and with solid crystals. Liquid crystals, when heated between cover glasses to a point slightly above that at which they pass into ordinary liquids, retain on cooling the original direction of their optic axes owing probably to condensation and consequent higher melting point of a layer on the surface of the glass. Isomorphous liquid crystals exhibit the phenomena of diffusion and hence the capability of solids to form mixed crystals appears to correspond exactly with the process of mixing or diffusion in liquids.—*Ann. Phys. Chem.*, xli, 525.—*J. Chem. Soc.*, lx, 249, March, 1891.

8. *On the Refractive indices of Water.*—BRÜHL has measured the refractive indices of water for light of certain wave-lengths

not hitherto employed. These are the double red line of potassium, of wave-lengths 0·770 and 0·767 μ, and the δ line of hydrogen, coinciding with the Fraunhofer line h, and of wave-length 0·4101 μ. In order to obtain the necessary brightness, the potassium bead was made of a mixture of potassium perchlorate and chloride; and it was placed at the point of the reduction-cone of the Bunsen flame. For the H_δ line, end-on spectrum tubes were employed, the light being bright enough to show even H_ε. Besides these lines, those of lithium, sodium and thallium were also used, and the lines H_α H_β, and H_γ in addition. A Fuess spectrometer reading to thirty seconds was employed, the minimum-deviation adjustment being secured for each kind of light and for each temperature. The following are the results obtained, each value being the mean of a series of measurements which the author believes correct to the fourth decimal place at least:

Temp.	K	Li	H_α	Na	Tl	H_β	H_γ	H_δ
19·9°	1·32888	1·33088	1·33120	1·33305	1·33493	1·33720	1·34045	1·34239
23·7°	1·32881	1·33077	1·33091	1·33280	1·33468	1·33692	1·34016	------
25·3°	1·32852	1 33041	------	1·33249	1·33447	------	------	------
26·0°	------	------	1·33050	------	------	1·33625	------	------
27·0°	1·32830	1·33033	------	------	1·33428	------	------	------

These results are compared with those obtained by v. d. Willigen, Landolt, Wüllner and Rühlmann for all the lines except K_α and H_δ and show a close accordance.—*Ber. Berl. Chem. Ges.*, xxiv, 644, Mch. 1871. G. F. B.

9. *Genesis of the Elements.*—Professor William Crookes closes a most interesting address before the Institution of Electrical Engineers on the subject "Electricity in transitu: from plenum to vacuum," with the following remarks on the genesis of the elements:—

It is now generally acknowledged that there are several ranks in the elemental hierarchy, and that besides the well-defined groups of chemical elements, there are underlying sub-groups. To these sub-groups has been given the name of "meta-elements." The original genesis of atoms assumes the action of two forms of energy working in time and space—one operating uniformly in accordance with a continuous fall of temperature, and the other having periodic cycles of ebb and swell, and intimately connected with the energy of electricity. The centre of this creative force in its journey through space scattered seeds, or sub-atoms, that ultimately coalesced into the groupings known as chemical elements. At this genetic stage the new-born particles vibrating in all directions and with all velocities, the faster-moving ones would still overtake the laggards, the slower would obstruct the quicker, and we should have groups formed in different parts of space. The constituents of each group whose form of energy governing atomic weight was not in accord with the mean rate of the bulk of the components of that group, would work to the outside and be thrown off to find other groups with which they

were more in harmony. In time a condition of stability would be established, and we should have our present series of chemical elements, each with a definite atomic weight—definite on account of its being the average weight of an enormous number of sub-atoms, or meta-elements, each very near to the mean. The atomic weight of mercury, for instance, is called 200, but the atom of mercury, as we know it, is assumed to be made up of an enormous number of sub atoms, each of which may vary slightly round the mean number 200 as a centre.

We are sometimes asked why, if the elements have been evolved, we never see one of them transformed, or in process of transformation, into another. The question is as futile as the cavil that in the organic world we never see a horse metamorphosed into a cow. Before copper, e. g., can be transmuted into gold, it would have to be carried back to a simpler and more primitive state of matter, and then, so to speak, shunted on to the track which leads to gold.

This atomic scheme postulates a to-and-fro motion of a form of energy governing the electrical state of the atom. It is found that those elements generated as they approach the central position are electro-positive, and those on the retreat from this position are electro-negative. Moreover, the degree of positiveness or negativeness depends on the distance of the element from the central line; hence, calling the atom in the mean position electrically neutral, those sub-atoms which are on one side of the mean will be charged with positive electricity, and those on the other side of the mean position will be charged with negative electricity, the whole atom being neutral.

This is not a mere hypothesis, but may take the rank of a theory. It has been experimentally verified as far as possible with so baffling an enigma. Long-continued research in the laboratory has shown that in matter which has responded to every test of an element, there are minute shades of difference which have admitted of selection and resolution into meta-elements, having exactly the properties required by theory. The earth yttria, which has been of such value in these electrical researches as a test of negatively excited atoms, is of no less interest in chemistry, having been the first body in which the existence of this sub-group of meta-elements was demonstrated.

10. *Geschichte der Photographie;* by C. SCHIENDL. pp. 380, small 4to, Vienna (Hartleben).—The author commences with a brief review of what few observations were made by the ancients upon the action of light, which seem to have amounted to very little, and then passes to the early beginnings of photography in modern times. These chapters are full of interest. From his investigations the author concludes that the first actual image produced by light was obtained by J. H. Schulze in 1727 who observed that a mixture of nitric acid, silver nitrate and lime in excess produced a compound which darkened in sunlight but that the portion under the piece of cord, which he tied around the flask

in which the matter was contained, remained white. Only at long intervals were further steps made. Thirty years later Beccaria made the observation that the coloring of silver chloride was due to the action of light and not as previously supposed, to that of the air. In weighing the relative claims of Nicéphore Niépce and of Daguerre to the actual discovery of photography the author is disposed to believe that the former has received too little and the latter more than his due share of the honor. The discoveries which rapidly followed after this are next described and the author has evidently devoted much care and thought to the presentation as well of the theoretical views as of the practical processes which have been brought forward up to the present time.

The book seems to deserve a translation into English. M. C. L.

11. *Die Elektrischen Verbrauchsmesser von* Etienne de Fodor. 219 pp. 12mo. Vienna, 1891.—Electro-technical Library, vol. xliii (A. Hartleben). The electro-technical library, the earlier issues of which have been noticed in the Journal, has grown to upwards of 40 volumes covering a wide range of topics. It would be difficult to find elsewhere so much direct practical information on subjects dealing with the technical application of Electricity, as is compressed into these little volumes. The present issue takes up the subject of Electric meters and with great fullness gives the many forms that have been devised, from the earliest kinds first described to those now found most practically useful. The forms described are so numerous that the account of each is brief, but the abundance of illustrations adds much to the completeness of the treatment.

12. *Das Totalreflectometer und das Refractometer für Chemiker*, ihrer Verwendung in der Krystalloptik und zur Untersuchung der Lichtbrechung von Flüssigkeiten von Dr. C. Pulfrich. 144 pp. 8vo, with 4 plates. Leipzig, 1890 (Wm. Engelmann).—This volume contains a thorough discussion of the theory and practical use of the new form of totalreflectometer, first described by the author in 1887 (Wied. Ann., vol. xxx, p. 193). The method consists, in a word, in determining the critical angle for the light-ray which has passed from below into a glass cylinder and suffered total reflection from the surface of the substance under examination placed upon the plane surface of the cylinder. The required refractive index is given by the equation $n = \sqrt{N^2 - \sin^2 i}$ where N is the index for the glass and i the angle of emergence. By using different kinds of glass from $N = 1{\cdot}95$ to $1{\cdot}60$, refractive indices from 1·675 to 1·249 may be determined. The method is easy of application and, as shown by measurements by the author and others by Mühlheims, capable of giving accurate results. A special chapter describes the modification of the instrument as designed for the use of chemists in the measurement of refractive indices of solutions.

13. *Appleton's School Physics;* embracing the results of the most recent researches in the several departments of Natural

Philosophy by J. D. QUACKENBOS (literary editor), A. M. MAYER, F. E. NIPHER, S. W. HOLMAN, F. B. CROCKER. 544 pp. New York, Cincinnati, Chicago, (Amer. Book Co.—D. Appleton Co.'s Press). It is satisfactory to receive an elementary work on Physics which, like the one in hand, is fresh and new throughout, and not an abridged reproduction of matter and illustrations which have done duty for many years. The limitations of a book for early students in a subject so large and profound are severe, and it would not be difficult here to find points to criticize, but the manner in which the several editors have done their work is deserving of decided commendation. The simplicity of the treatment and the practical character of the illustrations make the book particularly well suited for the class of students for which it is written; it should have a wide sphere of usefulness.

14. *Handwörterbuch der Chemiker.* By Dr. CARL SCHAEDLER. 12mo, pp. vi, 162. Berlin, 1891 (Friedlander).—A series of brief biographical sketches of eminent chemists and physicists. The Americans noticed are the two Sillimans and Remsen.

15. *Bibliotheca Polytechnica:* a Directory of Technical Literature. By V. SZCZEPANSLI. 12mo, pp. 80. New York, 1890. (Int. News Co.).—A classified catalogue of technical books and periodicals published in America and Europe.

II. GEOLOGY AND NATURAL HISTORY.

1. *On the Rock-fracture at the Combined Locks Mill, Appleton, Wisconsin;* by FRANK CRAMER. (Communicated.)—It was impossible, after the upheaval of a part of the pulp-mill at the Combined Locks, in September, 1889,* to get direct evidence of movement in the underlying rock. During the past summer, the water was pumped out of the tail-race for the purpose of deepening the latter, and this gave an opportunity to examine the rock layer on which the mill rests. It will perhaps be well to describe the fracture in the rock under the mill, to show how accurately the cause was registered in the effects.

What the extent of the disturbance was just outside of the cement pier and above the dam, cannot be known. But inside, under the mill, the crack in the rock begins directly under the big crack in the pier and runs under the piers supporting the sixth, seventh and eighth machines and close to those supporting the third, fourth, fifth, ninth and tenth machines. It passes out under the sixth and seventh windows and ends in the quarry in the tail-race just below the mill. The rock is lifted into a low ridge which gradually dies away toward the quarry. The effects of the compression are most marked near the big pier. Here the rock on one side of the fracture is lifted nearly a foot, while on the other side it has fallen back nearly into its original position, leaving a fault of eight inches. Along the line

* See this Journal, xxxix, 220, 1890.

of fracture the rock is broken into pieces varying in size from a few square inches to several square yards. The fault disappears where the crack passes out from under the mill; and here the splintering is confined to a depth of two or three inches and a width of four or five. The chips vary in size from half an inch to two or three inches square, and many of them are scarcely thicker than a sheet of paper. Beyond this the ridge, the fault and the crushed rock disappear and there is nothing to indicate a disturbance, except a clean fracture, which ends in the quarry.

There have been observed, in this region, two or three other cases of fracture which will throw light in the search for the cause of the fracture at the Combined Locks. Between the last two locks in the government canal at Kaukauna, about sixteen inches of the upper rock layers had been removed, leaving a layer three and a half inches thick at the surface in the bottom of the canal. Before navigation opened last spring the canal bed was examined, and this upper layer was found fractured and raised into a ridge for a distance of about twenty-five feet along a line of drill-holes that had passed through it. It was proved beyond a doubt by the conditions observed on the spot and by the testimony of men who helped remove the rock in the canal, that the ridge was not formed until at least one season after the canal had been finished and in use. The one layer was raised sixteen inches, leaving a hollow underneath. The fracture passed along the line of the drill-holes, and formed the axis of the ridge. Its direction was N. 20° E. parallel with that of the canal and the river.

Only a few hundred feet away from the canal another break in the rock occurred in June, 1889. At this point the high clay bluff bends away from the river, leaving a large flat, but little above the river level, and with the rock almost bare of soil. On this flat, at the south end of private claim 33, there was a quarry four and a half feet deep. A six-inch layer of limestone formed the floor of the quarry, at one end of which a hole seventeen inches deep had been blasted as a start for the next "level." The water was pumped out of the quarry in June; and after four or five days of warm weather, while some men were working just behind a knoll, they heard a noise which they described as being like that of exploding dynamite. The layer forming the floor of the quarry was fractured; the crack started from the hole at one end and ran down the middle of the quarry for some distance, and then bifurcated, the branches running to the two corners at the south end. The rock was lifted into a ridge sixteen inches high, and in some places split into thin plates. The fracture ran at right angles to the river and the high clay bank.

A paper mill has recently been built at Kimberly, three miles down the river from Appleton, and three miles up the river from the Combined Locks. A large quarry four feet deep was opened in the river bed below the government dam. While Mr. Charles Riggs, the contractor, and the men at work in the quarry were

eating dinner one bright day, they heard a snapping noise. The rock in the bed of the quarry was ripping. The disturbance started at the lower end, traveled up the river, and ended in a wheel-pit fifty feet square and four feet deep. It required several seconds to make the trip, and shook up the "quarry chips" that covered the bottom of the quarry to the depth of about a foot. Later, when the covering of the chips were removed and the quarry cut deeper, it was found that the first eight inches of the rock was broken by a clean fracture, but below that, was much crushed. How far down the crushed condition extended is not known; the quarry was made two feet deeper, and crushed rock was still in sight. The direction of the crack was N. 45° E.

When the several cases of fracture described above, all of which occurred in the compact Galena limestone of the Fox River valley, are considered together, it becomes clear that the weight of the clay plain had nothing to do with their production, for some of them run parallel with the river and the high clay banks, and others make high angles with them. And, further, there is no parallelism among the cracks themselves. The times of the year and other conditions under which the disturbances occurred make it impossible to assign a common local cause for them, and it is as difficult to point out a separate cause for each. It seems evident that the cause of the fractures is a condition of the rock itself; and that in this region it is suffering compression in all directions. The local character of the disturbances is well illustrated by the fracture at the Combined Locks, where at one end there were crushing, uplifting and faulting, and less than 125 feet away there is nothing but a simple fracture. The direction of fracture seems to be determined, not so much by preponderance of pressure in a particular direction as by the artificial relief given in each case. The local conditions, perhaps even including barometric disturbances, seem to furnish nothing but the occasions for the action of the general cause. The facts are in harmony with Gilbert's theory that the superficial strata have expanded in consequence of their rise in temperature since the close of the glacial period. But more data are needed for a demonstration.

Lawrence University, Appleton, Wis., Jan. 10, 1891.

2. *Bulletin of the Geological Society of America, Vol. II.*— The papers read at the December meeting, already published, include the following: C. L. Herrick, on the Cuyahoga Shale, and the problem of the Waverly; G. F. Becker, on the structure of a portion of the Sierra Nevada; Ed. V. D'Invilliers, on the Navassa phosphate deposits; A. Winchell, a last word with the Huronian; C. W. Hayes, on the overthrust faults of the Southern Appalachians; Robert Bell, the nickel and copper deposits of Sudbury District, Canada, with an appendix on the silicified glass-breccia, by G. H. Williams; Geiger and Keith, on the strucure of the Blue ridge near Harper's Ferry; G. M. Dawson, Geological structure of the Selkirk range; G. F. Becker, on Antiquities

under Tuolumne Table Mountain, Cal., and notes on the early Cretaceous of California and Oregon; R. Pumpelly, on the relation of Secular rock-disintegration to certain transitional crystalline Schists; A. Winslow, on the geotectonic and physiographic geology of Western Arkansas; W. Upham, on Glacial lakes in Canada; C. R. Keyes, stratigraphy of the Carboniferous in Central Iowa; E. Brainerd, on the Chazy in Champlain valley; G. H. Williams, on the petrography and structure of the Piedmont Plateau in Maryland, with a supplement by C. R. Keyes; J. Le Conte, on the Tertiary and Post-tertiary changes of the Atlantic and Pacific Coasts; J. E. Wolff, on the Lower Cambrian age of the Stockbridge limestone; H. D. Campbell and W. G. Brown, composition of Mesozoic igneous Rocks of Virginia; W. H. Weed, on the Cinnabar deposits and Bozeman coal fields of Montana; H. W. Turner, on the Geology of Mount Diablo, Cal., with a supplement on the chemistry of the rocks by W. H. Melville.

3. *Cambrian fossils in the Stockbridge limestone of Vermont.*—J. E. Wolff, in his paper in vol. ii of the Bulletin of the Geological Society of America (page 331), mentions the very important discovery of Lower Cambrian fossils in the great central limestone belt of Vermont, at several localities in the vicinity of Rutland. The fossils are a species of *Kutorgina*, and a *Salterella*, much like *S. currata* of the Olenellus Cambrian of North Attleboro, Mass. The limestone belt has, on its east side, with conformable bedding, the Green Mountain quartzyte, which Walcott proved, by the discovery of fossils, to be Lower Cambrian. West of the Limestone belt and dipping beneath it there is a second quartzite, that of Pine Hill, which also is referred to the Olenellus Cambrian. West of this there is a Center Rutland belt of limestone which was proved by fossils to be of Lower Silurian age, like that of the West Rutland limestone. Dr. Foerste was associated with Mr. Wolff in the discoveries.

4. *Geological Survey of Kentucky.*—This survey under John R. Procter, Director, has recently issued a report on the Geology of Clinton County, by R. H. Loughridge, M.D., and another on Whitley County and a part of Pulaski, by A. R. Crandall, assistant. Each is illustrated by a colored geological map, and the latter also by several plates.

5. *Geological Survey of Missouri.*—Bulletin No. 4 of this Survey contains descriptions of a large number of new species of Crinoids, from the Subcarboniferous beds of Missouri, by S. A. Miller, with figures illustrating them on four plates. A Biennial report by Mr. Winslow, the State Geologist, has recently been issued, which gives a sketch of former geological surveys in Missouri, and an account of the work now going forward.

6. *Geological Survey of Arkansas.*—J. C. Branner, State Geologist. The annual report for 1889, vol. ii, covering 283 pages, is devoted to an excellent detailed account of the geological structure and the resources of Crowley's Ridge, by R. Ellsworth Call. Crowley's Ridge, the only marked prominence in the

country between Little Rock and Memphis, rises usually over a hundred feet above the level of the country on either side of it. A colored map accompanies the report.

7. *Geological Survey of Texas.*—The annual appropriation for the Geological Survey of Texas, made by the Legislature just adjourned, is $35,000, exclusive of printing. Appropriations were also made for testing the lignites, for the publication of an accurate map of the State, and for the erection of a laboratory building at the University of Texas, which will contain a suite of rooms for the chemical department of the Survey.

8. *Geological Survey of Alabama.* — Professor Eugene A. Smith informs the editors that the last legislature of Alabama placed the annual appropriation for the geological survey at $7500, and made it continuing, i. e. till otherwise provided by law. This puts the survey on a very desirable footing as to permanence as there will be no effort to bring the work to a close so long as there is anything to report upon, which in the case of such a state as Alabama, will be a long while. The printing, engraving, etc., are paid for out of another fund, which leaves the whole amount of the appropriation to be devoted to the defraying of the general expenses of the survey. The first work to be undertaken will be the detailed mapping of the Warrior and Coosa Coal Fields.

University Ala., Feb. 23, 1891.

9. *A Bibliography of Palæozoic Crustacea from 1698 to 1889*, including a list of North American species and a systematic arrangement of genera; by Anthony W. Vogdes. 1890. 117 pp. (U. S. Geological Survey, Bulletin 63).—This work, which has been long announced, will meet a warm welcome from students of fossil Crustacea. The bibliography (Part I), extending from pp. 13–78, is a compilation noteworthy for its few omissions, and is unquestionably the most exhaustive analysis of the literature of these fossils yet produced. The citations consist of the titles in full, with a summary of the genera discussed, and frequent critical notes upon genera or species. An excellent feature of these citations is the more extended notice given to works of early date and those accessible with difficulty. If future editions would give, even at the necessity of considerable increase in size, the names of species as well as genera discussed in each work cited, it will prove a valuable addition. Species are the important units; generic values are constantly varying with the increase of knowledge. Part II is a systematic catalogue of the North American Paleozoic Trilobita, preceded by a brief synoptical table of genera and Part III is a similar list of the non-trilobitic species. In these catalogues Captain Vogdes has kept himself singularly free from the expression of personal convictions of generic and specific values, preferring to accept the latest results of reliable investigation as standards. In this respect the catalogue possesses a value not shared by previous attempts in this direction which have been carried on without special familiarity

with these fossils. The author's convictions are however often apparent, even when not enforced. For example, he adopts the term *Trinucleus*, though expressing the opinion that Dr. Green's *Cryptolithus* is entitled to acceptance; again the genus *Acidaspis* is retained in its broad and current usage, though Captain Vogdes himself has at an earlier date warmly and justly espoused the precedence of Warder's term, *Ceratocephala;* in these and other instances evincing his consideration for the convenience of those who will make the most use of the work. But two new generic names are proposed, *Lloydia* (in honor of Edward Llhwyd "the first author on Trilobites") for the species *Bathyurus bituberculatus* Billings, and *Strigocaris*, in place of *Solenocaris* Meek, a preoccupied term. The catalogue of non-trilobitic genera is preceded by a scheme of classification which is open to objection in some respects. The author does not choose to recognize Packard's order *Phyllocarida*, but divides the *Phyllopoda* into the *Ceratiocaridæ*, *Discinocaridæ* and *Rhinocaridæ* and in the last family are placed *Estheria*, *Leaia* and *Schizodiscus* (perhaps the only genuine phyllopods in the list) as well as the genus *Mesothyra*, which belongs to the distinct family, *Pinacaridæ*.

The entire work is unfortunately abundant in typographical errors, few, however that need cause serious annoyance. Some of these have already been corrected in a supplement issued by the author privately, and it may be expected that others will be eliminated in the future editions which, it is hoped, so valuable a catalogue will attain. J. M. C.

10. *On the Organization of the Fossil Plants of the Coal-Measures;* by W. C. Williamson. Pt. XVII. Phil. Trans. Roy. Soc. London, vol. 181. 1890, B, pp. 89–106, pl. XII–XV.—Part XVII of this series of valuable memoirs is important for the evidence which it contains of the discovery of an exogenous development among the Carboniferous ferns. The anticipation expressed by the author in Part IV that *Dictyoxylon* (*Lyginodendron*) *Oldhamium*, there described as belonging to Paleozoic Proto-gymnosperms might be identical with the petioles described, at the same time, as Edraxylon, and later (Pt. VI) as *Rachiopteris aspera*, is now confirmed, and the two are conclusively proved to be trunk and petiole of the same plant. The origin of the trachæal bundles of the petiole in the middle cortex of the trunk and the formation of the medulla in the center are described with the author's customary accuracy and minuteness of detail. As the medulla expands during the growth of the petiole, there is a corresponding increase in the number of vascular laminæ, the inner extremities of which, though commencing their growth at different periods of life, all start from the medullary border of the vascular zone and extend to the periphery. The number of these laminæ were observed to vary from 44 in a small specimen, in which the medulla was present, to 1120, similarly arranged, in a large one. Not only has Prof. Williamson examined many specimens showing the transition stages between the two types, but

his studies include specimens in which stem and petiole are organically united, thus rendering more conclusive the proof that *Lyginodendron Oldhamium* is a true fern, probably belonging to the Sphenopterids, and that the stems of some, at least, of the Carboniferous ferns "developed their xylene or vascular structure exogenously through the instrumentality of a meristemic zone of the innermost cortex, which practically must be regarded as a cambium layer." D. W.

11. *Catalogue of the Fossil Cephalopoda in the British Museum, Part II;* by ARTHUR H. FOORD.—Although nominally a catalogue, this work possesses the nature of a monograph, and is a positive contribution to the literature of the subject. A full bibliographical notice is given of each genus and species, together with detailed descriptions of the principal characters. The present volume includes the families Lituitidæ, Trochoceratidæ, and Nautilidæ. The text is enriched with numerous wood-cuts drawn by the author. C. E. B.

12. *Mineralogical notes*, by W. E. HIDDEN and J. B. MACKINTOSH. (Communicated). *Auerlite.*—The lemon-yellow variety found on Price's Land in Henderson County, N. C., has proved to contain more P_2O_5 and correspondingly less SiO_2 than that from the Freeman Zircon Mine, three miles northeasterly in the same county. The density varies between 4·051 and 4·075. The ratio of $P_2O_5+SiO_2 : H_2O$ is the same as is demanded by the formula deduced from the former analyses. It is to be noted that the density decreases as the percentage of phosphoric acid increases. Among the crystals we have observed twins parallel to 1-*i*, as in zircon, rutile and cassiterite. The analysis has given :

		Molecular Ratio.		
P_2O_5	$8·58 \times \frac{5}{142}$	362	}	·590 = 1
SiO_2	$6·84 \times \frac{2}{60}$	·228	}	
ThO_2	$[72·16] \times \frac{2}{264·5}$	·553	} × 2	1·172 = 2
Fe_2O_3	$1·78 \times \frac{3}{160}$	·033	}	
H_2O	$10·64 \times \frac{2}{18}$	1·182		= 2
	100·00			

The thoria was tested and found to be quite pure but was unfortunately lost before it could be weighed. The percentage above given is determined by difference. The above analysis confirms the formula previously assigned by us to this mineral (see this Jour., Dec. 1888, p. 462) i. e.,—$ThO_2, \left\{ \begin{matrix} SiO_2 \\ \frac{1}{3}P_2O_5 \end{matrix} \right\} 2H_2O$ or a thorite (orangite) in which part of the silica is replaced by its equivalent in phosphoric acid, when $3SiO_2 = 1P_2O_5$. The P_2O_5 tends to be in excess.

Sulphohalite $[Na_2(\frac{3}{4}SO_4, \frac{1}{4}Cl)]$.—A careful examination of the few crystals available has proved an apparent tendency to hemihedrism, the octahedral faces being present only on the alternate trihedral solid angles of the dodecahedron. This, if confirmed,

would make the species tetrahedral like boracite, but this we cannot however assert positively on account of the present rarity of the mineral. Besides these faces of the octahedron (or tetrahedron) we have also observed the cube modifying the rhombic-dodecahedron. One very perfect crystal contained an irregular cavity full of a liquid in which was a moving bubble of air (or gas.) It also showed, by transmitted light, numerous lines of growth parallel to all the planes.

*On the composition of the Fayalite from Cheyenne Mt., Colorado.**—This mineral has the high specific gravity of 4·35, shows cleavage, (imperfect) at right angles in two directions, is fusible and gelantinizes with acids. It occurred in this instance as a mass weighing nearly ten pounds and was quite abundant in the vicinity in the granite. Analysis leaves no doubt as to its nature. The results were:

	1.	2.
SiO_2	27·30	27.66
FeO	5·83	65·794
MnO	....	4·17
CaO	....	0·47
		98·24

The iron may be present in both the ferrous and ferric state but this point was not determined, or the reasons for the loss ascertained.

13. *Mineralogical Notes;* by W. E. Hidden, (communicated.) —*Remarkable discovery of Bastnaesite and Tysonite.*—In the summer of 1889, Mr. J. G. Hiestand, of Manitou Springs, Colorado, brought to my attention and sent samples of a new discovery of bastnaesite and tysonite, which he had made in the Pike's Peak region, at no very great distance from Manitou. He reports that the total quantity found weighed over six kilograms and was originally all included in one great group or mass. Hexagonal tabular crystals, somewhat modified, nearly two inches across, of a clear deep brown color, made up the exterior layers of the larger fragments while the interior and greater portion was composed of the wax-yellow unaltered tysonite, in parts perfectly transparent. The specific gravity of several fragments was found to be only 6.007. For novelty's sake a gem was cut that weighed two-thirds of a gram, but it did not have very much brilliancy. Some sections were made for optical examination and have been sent to Prof. Penfield for that purpose.

A white mineral of an earthy nature and seemingly a product of alteration occurs in the bastnaesite and tysonite in large patches. Its specific gravity = 4·145. It lost 21·02 per cent after being strongly ignited and was then wholly soluble in HNO_2 making a deep red solution, (Ce). It may prove to be a mixture of bastnaesite with lanthanite.

* See this Journal, March, 1885, p. 250.

Four new localities of Fergusonite.—Along with the orthite found near Amelia Court House, Virginia, I have discovered a few small crystals of fergusonite implanted upon it at right angles and projecting into the feldspar matrix to a depth, in some instances of 18 to 20^{mm}. The prisms were square with very dull gray surfaces, but were brilliant resinous on a fractured surface. The terminations were obscure but traces of acute octahedra were noticed. Sp. grav. varied from 5· to 5·6. No analysis was attempted.

With the three hundred or more pounds of zircon mined by the writer in the near vicinity of Storeville, Anderson County, South Carolina, several crystals of a highly hydrated fergusonite have been found, some of which might more properly be termed an "yttro-gummite." Corundum, garnet and columbite were also observed to exist quite commonly in the region.

From near Spruce Pine, Mitchell County, North Carolina, I have received several ounces of very fair crystals of fergusonite exhibiting externally various stages of alteration. It is said to have been found in the dump heaps of the Grassy Creek Mica Mine. As a contact association I have found allanite and cyrtolite. The basal plane was prominent. One crystal weighed over twenty grams. Its behavior upon ignition was very characteristic and in all respects similar to the Texas mineral.

In the early part of last year I observed this species as a quite frequent occurrence in the gold placers of the mines near Golden P. O., Rutherford County, N. Carolina; with such associates as xenotime, malacon, monazite, rutile, etc.

On the "Orangite" from Landbö, Norway.—A partial examination of this mineral, made on several grams of transparent resin-yellow massive material, has proved it to belong to the variety of thorite called *uranothorite*, like the mineral described by Collier and the Norwegian specimens later analyzed by Lindström and by Nordenskiöld, and referred to uranothorite by Brögger. Its specific gravity = 4·322. It lost upon ignition (H_2O) 11·97 pr. ct. and contained 18·50 pr. ct. SiO_2; 52·53 pr. ct. ThO_2; 9·00 pr. ct. UO_3; 1·32 pr. ct. PbO and small amounts of lime and iron. Little if any of the cerium or yttrium earths are present, other ingredients were not looked after. It crushes into a creamy white powder which becomes dull green after strong ignition. A translucent red-brown variety, or partial alteration, has sp. gr. = 4·303.

An opaque earthy brown mineral having a black, pitchy looking core has been sent out from the same locality under the name of "thorite," but its low density (4·2) and the abundance of water, uranium and lead present, lead me to believe that it is only an impure variety of uranothorite. I have worked up over one kilogram of it and found it to contain about 45 per cent of thoria and 1 per cent of yttria earths.

14. *Tenth Annual Report of the State Mineralogist of California* for the year ending December 1, 1890. 983 pp. Sacra-

mento, 1890.—The tenth Mineralogical Report of California, issued by Wm. Irelan, Jr., State Mineralogist, is a weighty volume of nearly 1000 pages, illustrated by many plates, maps and profile sections, and accompanied by a large geological and mineralogical map of the State on a scale of 12 miles to the inch. Detailed accounts are given of the mining operations in the several counties; these chapters are contributed by a number of different observers, including W. A. Goodyear, H. DeGroot, E. B. Preston, J. B. Hobson, M. Angell, W. L. Watts and others. The colored geological map mentioned is compiled from the twenty-five atlas sheets by the State Engineering Department which are on a scale of 4 miles to the inch.

15. *Allgemeine Chemische Mineralogie* von Dr. C. DOELTER. 277 pp. 8vo. Leipzig, 1890 (Wm. Engelmann).—The fact that the author of this work has already made many important contributions to the subject of mineral chemistry both on the analytical and synthetic sides gives us a right to expect a very clear and thorough presentation of the subject from his pen and in this he has not disappointed us. The successive chapters are devoted to the general chemical relations of mineral compounds, with a discussion of isomorphism, isogonism, etc.; chemical analysis both in the wet and dry way; mineral synthesis; the alteration of minerals and their formation in nature, and finally a summary of all prominent mineral species with a statement of their composition. Of these various topics, we turn with most interest to the chapters which give an excellent summary of the present state of knowledge of artificial minerals, a subject which has been rapidly developed during the past two decades and one in which the author's contributions are not inferior to those of any other German mineralogist.

16. *Index der Krystallformen der Mineralien*, von Dr. VICTOR GOLDSCHMIDT.—The announcement of the publication numbers 4 and 5, of volume iii, made in the March number, is quickly followed by the appearance of number 6, including the species from Xanthokon to Zunyite. This concludes the work with the exception of a supplementary number which is to be devoted to errata, etc.

17. *Gray's Manual of Botany;* reprint of the sixth edition, edited by Dr. SERENO WATSON and Prof. J. M. COULTER, 1891.—In the revision of Gray's Manual which appeared about a year ago, the editors earnestly solicited information of any additions or corrections which might appear necessary. In generous response to this request a number of botanists in different parts of the country have reported such additional details or alterations as, from their personal observation, they judged desirable. In the second issue of the sixth edition, which has recently been put upon the market, and to which we take pleasure in calling attention, these additional details have received due recognition. A number of minor alterations have been made in the plates of the text, and are thus scattered through the work. Such changes, however, have naturally been limited; and the chief new feature

of the reprint is a supplement of four pages, containing over a hundred additions and corrections. Among these changes, those very naturally predominate which extend the geographical range of species and varieties. Two genera, *Franseria* and *Paulownia*, and some dozen species and varieties have been added, being chiefly introduced plants, which have escaped from cultivation within the limits of the Manual. As book-dealers still have a part of the first issue to dispose of, persons especially desiring the corrected reprint should be careful to secure copies containing the four pages 735*a*, *b*, *c*, and *d*. B. L. R.

18. *Hypertrophie des lenticelles chez la pomme de terre et quelques autres plantes ;* (Bull. soc. bot. de France, ser. II, tome xiii, pp. 48–50).—In this brief communication to the French botanical society H. Devaux gives an account of a remarkable modification in the development of lenticels when submerged in water. His experiments were chiefly made upon growing tubers of the potato. These he found were "asphyxiated" if completely submerged, but would live and continue their development if only partially covered with water. In the latter case, however, the lenticels, which are rather numerous, underwent a peculiar modification, increasing considerably in size, becoming conical, and opening so that a loose tissue protrudes from within. The interesting feature in the description is that the loose tissue thus formed closely resembles that modification of cork which normally occurs in certain swamp plants, and which H. Schenk has called *aerenchyma*. It is a secondary tissue characterized by thin-walled cells but slightly attached to one another and separated by very large intercellular spaces filled with air or other gases. As Dr. Schenk has shown, this tissue probably plays an important part in the aeration of submerged or partially submerged plants. The production of the same sort of tissue in the lenticels of the potato, as described by Devaux, appears therefore an especially interesting example of the power of adaptation, which a plant may exhibit when placed in unusual conditions of growth. B. L. R.

19. *The Nursery-Book, a complete Guide to the Multiplication and Pollination of Plants ;* by Prof. L. H. Bailey. (New York, 1891, 16mo, 300 pp.)—In this neat little volume the author gives concise descriptions of the numerous forms of artificial reproduction practically applied in the cultivation of plants. The various methods of grafting, layering and propagation by division receive their proper attention, and details of manipulation and appliances for work are illustrated by numerous wood-cuts. In an extended alphabetic list of cultivated plants the best methods of propagation to be employed in individual cases are enumerated, together with valuable hints in regard to proper treatment. The closing chapter deals rather briefly with artificial pollination and hybridization. The whole work is a model of clearness and practical simplicity which will make it a valuable aid alike to professional nurserymen and to amateurs in plant-culture. B. L. R.

20. *Die Organisation der Turbellaria Acœla*, von Dr. LUDWIG VON GRAFF, Professor of Zoology and Comparative Anatomy in the University of Gratz. 90 pp. quarto. Leipsic, 1891 (Wilhelm Engelmann).—This work is an elaborate memoir on the Acœlous Turbellarian worms. It is illustrated by ten plates, exhibiting their microscopic structure as presented in different species of the genera Amphichœrus, Convoluta, Aphanostoma, Monoporus and Proporus. An especially interesting part of the volume is a supplement, on the structure and purpose of the chlorophyll cells of *Convoluta Roscoffensis*, by Dr. G. Haberlandt, Professor of Botany in the same university.

III. MISCELLANEOUS SCIENTIFIC INTELLIGENCE.

1. *Note on the recent eruption of Kilauea, Hawaii.*—A letter, from Rev. E. P. BAKER, of Hilo, dated March 8th, states the following facts:

The eruption, or discharge of Halemaumau, mentioned on page 336, occurred on the 6th of March—the very same day of the year with that of 1886, making the interval just five years, and adding another to the number of Spring or wet-month eruptions. The lava ran out by some subterranean channel, at a slower rate than in 1886, a little of it still remaining on the 7th. The whole area gradually subsided and in two or three days, the cone had sunk out of sight, leaving in its place a crater-like cavity about as deep as that of 1886 [900 feet]. This crater has a talus half-way up from the bottom, making it conical below, and a sheer precipice above; and avalanches from the precipice continue to add to the talus. The diameters of the crater are by estimate three-fourths and half a mile.

There were earthquakes in Hilo for a week or so after the 6th of March, and many also in Kapapala, 15 miles to the southwest of Kilauea, but all were light. It is inferred that the lava ran out under ground, in the direction of the discharge of 1823. As in 1886, none appeared above ground. [The cone that was so deeply buried at the eruption was the "debris-cone," whose condition for 1887–1888 is represented on plates in Vol. xxxv of this Journal, and also in the writer's work on Volcanoes. It was early described by F. S. Dodge as resting on the liquid lava; and to this its whole history, and the final event of its burial, attest. J. D. D.

2. *Depths of* 3000 *fathoms and more in the Indian Ocean.*—An area having depths of 3000 fathoms and more exists off the Northwest coast of Australia. In addition to earlier observations between meridians of 100° and 106° E., and parallels of 18° and 25° S. new results were obtained in 1888 by the Eastern Telegraph Co.'s steamship "Recorder," under Capt. C. O. Madge. The depths found were from 3015 to 3393 fathoms, between the latitudes 13° 40′ and 11° 22′, and the meridians 118° 42′ and 116°

50′. The greatest depth was at the northeast extremity of this line, in latitude 11° 22′ and longitude 116° 50′. Just beyond, in latitude 11° 08′ and longitude 116° 38′, the depth found was 2860 fathoms.—*From the Report on Oceanic depths, issued by the Admiralty, Hydrographic Department*, London, Jan., 1891.

3. *Catalogue of the Crawford Library of the Royal Observatory, Edinburgh.* Edinburgh, 1890. This quarto of 500 pages in double columns contains the titles of the remarkable collection of books, pamphlets and manuscripts which the Earl of Crawford presented in 1888 to the Edinburgh Royal Observatory. Charles Babbage was a famous collector of rare and old books, and after his death his entire library was bought by Lord Crawford, in 1872, and to this were added rare books from the library at Haigh Hall and many other books, by purchase, so that this collection at Dunecht had become one of the notable astronomical libraries of the world. In the present catalogue the full title is given of each book and pamphlet, and the Edinburgh Observatory and its Astronomer Royal, Mr. Copeland, have thus added largely to our resources in the Bibliography of Astronomy.

4. *Dr. Goodale in New Zealand.*—The third session of the Australasian Association for the Advancement of Science was held in Christ Church, New Zealand, and began Jan. 15th, 1891. Sir James Hector, presided. The meeting was a successful one, the attendance being about 470, and the number of papers read 74. Prof. Goodale, of Harvard University, represented the American Association, but no member of the British Association attended from England.—*Nature,* March 26th.

5. *Missouri Geological Survey.*—Mr. Chas. R. Keyes of Des Moines, Iowa, has been appointed paleontologist of the Survey. Mr. Keyes is now at the Johns Hopkins University, Baltimore, but will report for duty in Missouri during the month of May. In the meantime he is occupied in the preparation of a report on the paleontology of the State, in which work he has already made considerable progress.

The Journal of Comparative Neurology: A quarterly periodical devoted to the Comparative study of the Nervous System. Edited by C. L. Herrick. Vol. I; pp. i–xviii, 1–106. Cincinnati, Ohio.

A Journal of American Ethnology and Archæology.—Editor J. Walter Fewkes. Volume I. 132 pp. 1891 (Boston and New York, Houghton, Mifflin & Co.)

OBITUARY.

James B. Mackintosh, of New York City, died on April 15th, after a brief illness, aged 34 years. He was a skillful, active chemist, and besides work on the technical side he had made important contributions to mineralogical chemistry and his future promised bright in this direction; recent volumes of this Journal contain a number of articles by him and one of which he is part author appears in the present number.

NEW MINERALS

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We have all that is in the market of each of the following:

Auerlite, a new Thorium silico-phosphate, found rarely with Zircon in Henderson Co., North Carolina. Only about 100 grams were found in a search of five weeks, and it is, therefore, likely to remain an exceedingly rare mineral. We have secured the original "find" upon which the species was described (see A. J. S., this number, p. 438, and Dec., '88). Price $1.00 per gram. A very few small, rough crystals at 50c. to $1.00 each.

Aguilarite, a new sulpho-selenide of silver, from Mexico, described in this number of the A. J. S., p. 401, was secured by our Mr. Niven during his last trip. Less than a dozen specimens have been found altogether, and all but one show more or less complete alteration to Stephanite. All the specimens are well crystallized. The excessive rarity of the new species and its high cost in the locality compel us to charge considerable for it, but we have some small specimens, portions of the type material, as low as $1.50 to $5.00.

Pollucite from Maine, described in A. J. S., March, '91. The entire find (except such as was presented to the describer) has been purchased by us. Specimens of this mineral are essential to the completeness of every collection. The amount of the find was very small and we have already sold two-thirds of it, so that our customers are urged to send in their orders promptly. Prices 50c. to $7.50.

Polycrase from South Carolina, described in A. J. S., this number, p. 423. We have picked over the entire "find" and have the best material there is, and *all* that will be sold as specimens. The crystals are mostly rough and fragmentary, but are much superior to any European specimens we have seen for sale. The high percentage of the rare element scandium and the fact that this is the first occurrence of Polycrase in the U. S. renders the specimens doubly desirable. Prices 10c. to 75c. each.

Monticellite from Arkansas, described in this number of A. J. S., p. 398, was first brought to notice by us. We can supply illustrative specimens at 25c. to $2.50.

Eudialyte from Arkansas, 25c. to $2.50.

For many other recent additions to our stock see our other page of announcements.

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GEO. L. ENGLISH'S ANNOUNCEMENTS.

Mr. Atkinson of our firm sailed on the Etruria, May 16th, for an extended collecting tour through Europe. We hope to announce next month some of the many important additions to our stock which we expect as the result of his trip.

Mr. Niven of our firm started May 9th on another long tour through the far West and Mexico. Already returns from Missouri and Colorado are reported and some remarkable specimens have come in. Among them is

A magnificent specimen of Minium, $6\frac{1}{2}$ by 4 by 2 inches, weighing over 5 lbs. We believe this specimen to be the finest ever found.

A mass of Horn Silver, nearly pure, 3 by $3\frac{1}{2}$ by $2\frac{1}{4}$ inches, weighing 2 lbs. 3 oz. was also secured by Mr. Niven. A much more wonderful specimen of this mineral has just been received from New Mexico. It is 7 by 6 by 4 inches and weighs over 12 lbs., and with the exception of a little native silver, the entire mass is pure chloride of silver, giving it a *bullion* value of over $125.00.

Gold beautifully crystallized and in wires, has also been received among other Colorado specimens from Mr. Niven, and some

Fine Wire Silver, Embolite, Epidote crystals, Cerussite crystals, etc., are in the same lot.

Missouri specimens include most beautiful "ruby blende" crystals, yellow calcites, etc.

Proustite from Chili. A superb group (2 by $2\frac{1}{2}$ by $1\frac{1}{2}$ inches) of stout scalenohedral crystals, $\frac{1}{4}$ to $1\frac{1}{4}$ inches long, has just come in. Another very beautiful small group.

Hiddenite crystals. A fine, large lot of singly and doubly terminated crystals has been secured this month. We can supply these gem crystals at lower prices than ever before.

Beryllonite crystals. We have succeeded in purchasing a large number of the best crystals ever found of this rare mineral, the lot embracing probably 75 to 100 choice crystals, besides many good cleavage specimens which latter we can sell as low as 10 cents each.

Childrenite crystals from Maine (new). A few very excellent specimens of this rare mineral have been received from a new locality in Maine. The find is well worthy of especial notice.

Other Rare Minerals Recently Added.

Durangite, fine crystals; **Roscoelite** from both Colorado and California; **Aguilarite,** the new sulpho-selenide of silver from Mexico; **Durdenite,** the new ferric tellurite from Honduras; **Auerlite,** the new hydrous silico-phosphate of thorium from North Carolina; **Polycrase** from South Carolina; **Monticellite, Manganopectolite, Leucite, Eudialyte,** etc., from Arkansas, **Pollucite** from Maine; **Axinite,** pale lemon-yellow crystallized **Willemite, Niccolite,** etc., from Franklin, N. J.; **Cacoxenite** from Pa., and many other equally desirable minerals.

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THE

AMERICAN JOURNAL OF SCIENCE

[THIRD SERIES.]

Art. LIII.—*The Study of the Earth's Figure by means of the Pendulum;* by E. D. Preston.

[Read before the Brooklyn Institute Feb. 26, 1891. Published by permission of the Superintendent of the U. S. Coast and Geodetic Survey.]

History.

The idea of finding the size and shape of the earth is probably one of the oldest in the history of science. Each age has added to the knowledge of the age before it, and each one has by its additions to existing data contributed to the solution of the problem. From the time of Anaximander 600 years before Christ, when it was thought to be a cylinder with a height equal to three times its diameter, down to the last deductions of Clarke and Bessel which point to a spheroid with three unequal axes, successive theories have been tested by physical observations and corrected or modified by the facts revealed by experience. It is not worth while to review all the ancients thought or did on this subject. Such a study would be interesting but not profitable for the present purpose. The turning points or mile-stones on this highway of inquiry may, however, be noted as showing how slow has been the progress towards what we now believe to be the truth. The cylindrical theory supposed the land and water to be on the upper base. Seven successive generations accepted this idea and when it was no longer considered tenable a cube was substituted for the cylinder. What a striking difference between the intellectual activities of an age that required several hundred years to pass from a cylinder to a cube, and was satisfied with this conclusion, and an age that in one-half the time has determined the distance of the heavenly bodies and studied

their composition. Aristotle, three centuries before Christ, supposed the earth to be spherical, and Eratosthenes 100 years later was the first to actually compute its dimensions from observations of the sun's shadow. Nothing of course was done in this direction in Europe during the dark ages. With the revival of learning in the 15th century the spherical theory again took shape and during the 16th (1525) Fernel determined the earth's dimensions essentially as it is done to-day; that is, by measuring the distance between two points and observing their difference of latitude. From this time on, it being admitted that the shape of the earth was something like a globe, the question was and still is, how much does the surface depart from that of a perfect sphere, and what is its actual size. In 1669 Picard measured the length of a degree by means of triangulation. This was a long stride in advance of all previous work, because here for the first time spider lines were used to mark the optical axis of the telescope. Newton used his value in the proof that the moon falls toward the earth in obedience to the law of universal gravitation. A score of years later Cassini greatly extended the measurement of arcs in France, but from some unfortunate circumstance his results were contrary to the Newtonian theory, and also to what had come to light a few years before, namely, that a pendulum vibrates much slower at the equator than in middle and higher latitudes. This gave rise to a controversy which brought about the famous work of the French academicians in Lapland and in Peru. Their labors effectually closed the question of the relative lengths of the polar and equatorial axes, and since then we have simply been making closer and closer approximations to the still unknown truth. From the accumulation of refined observations other knowledge than that directly sought has come to light. It is found that an ellipsoid better fits the observations than a spheroid, and there seem to be physical reasons why the northern and southern hemispheres should not be exactly equal. Moreover, the actual surface of the earth departs everywhere from the mean figure adopted in all theoretical computations, and it is generally admitted that this mean figure cannot be corrected until we know something more about the actual figure.

The quantities involved.

Now to recount: first we had the cylinder, then the cube, then the sphere with its variations into spheroid, ellipsoid and geoid. There is where we are at present; and what I shall have to say will be touching the instruments and methods by which the eccentricity, one element in the earth's figure, is

determined. Let us first understand what kind of quantities we are dealing with. The difference between two radii of the earth, one being polar and the other equatorial, is about thirteen miles. This bears the same relation to the whole radius that one inch bears to twenty-five feet. So that had we a model of the earth in its true proportions it would be quite impossible to see with the naked eye whether it was flattened at the poles or not. The first practical demonstration of a change of the force of gravity with a change of latitude was had a little over 200 years ago when a clock was carried from France to Guiana. This clock kept accurate time in Paris but lost two minutes per day in Cayenne. The pendulum had to be shortened about $\frac{1}{10}$ of an inch in order to make it beat seconds, as it had done in a more northern latitude. It was thus seen that the pendulum could be used to measure the force of gravity. The change in the time of one oscillation over limited areas is, however, very small; one mile in distance making a difference of one two-millionth of a second in the time of vibration; or stated in another way, a pendulum thirty-nine inches long that beats seconds at the equator would only have to be lengthened by $\frac{1}{5}$ of an inch to make it beat seconds at the pole. When we consider that one-quarter of the entire circumference of the earth only changes the length of the second pendulum by its $\frac{1}{200}$ part, it is evident that a change of latitude even for a country as large as the United States affects the pendulum by what may be called a minute quantity. Then the force of gravity changes with the elevation; but our highest mountains only alter the time of oscillation by $\frac{1}{1500}$ part when distance alone is considered, and the effect is even less than that if the attraction of the mountain is taken into account. Of this we shall speak later. It is thus seen that in all work pertaining to the measurement of the force of gravity we are obliged to deal with very small quantities and that methods must be devised delicate enough to appreciate them. How far these have been successful may be judged from the fact that independent determinations of the time of an oscillation do not differ as much as the one hundred thousandth part of a second. It is not asserted that differential gravity is always known to this degree of accuracy, but simply that there is no difficulty in making the pendulum repeat itself with no greater error than that mentioned. When we come to measure the absolute force of gravity, besides determining an interval of time, we are required to measure an interval of space. This can be accomplished with a degree of precision far exceeding that attained in the time measures. Not only is it much easier to obtain the one hundred thousandth part of a meter than to get the corresponding fractional part of a second, but the effect

of an error in the time of an oscillation is doubled when it is referred to the length of the pendulum; so that the weakest part of the entire investigation is the length of the time of one oscillation. For this reason it has been assumed that the pendulum can never be made to compete with metal bars in giving us a uniform standard of length. Whether it is better to refer our standards to the wave-length of light, or to some material thing involving permanence of capacity, is not in the exact line of our thought at present. Objections have been urged against both these methods. The former because it was supposed the earth might eventually move to a region of space where the wave-length of light was different, and the latter because a capacity-measure may change its three dimensions unequally so that the permanence of its capacity would be no proof of the permanence of one of its linear dimensions. What most concerns us is to know that the seconds pendulum is not our best standard of length.

Method of Study.

The most advantageous way of treating the figure of the earth is now conceived to be different from that employed hitherto. The measurement of an arc of the meridian by triangulation is not the best means of arriving at the flattening although it gives the actual size of our planet with an accuracy fully equal to the requirements of the case. The problem should be separated into two distinct investigations, and to each one of them methods should be applied, that will determine the unknown quantities to the best advantage. Let pendulum observations and the moon's parallax determine the flattening and let triangulation measure the actual size. Then we shall have each method working in a field where it has the greater power and the results will be correspondingly better. When the flattening is determined its value may be used as a known quantity in the equations that determine the length of the axes. This method is suggested by Professor Harkness. Admitting then that pendulum observations must be employed for the study of the earth's figure, what is the best way of doing it? Here we are confronted by two distinct schools. The Germans, followed by the Russians and Swiss, have always favored absolute determinations of gravity. The English stand as the exponent of the rival school and only measure differentially. The U. S. Coast and Geodetic Survey has followed both methods to some extent, and now seems to be favoring differential measures especially for a preliminary survey of the country. The difference between the methods is briefly this: the Germans measure the actual force of gravity

at every station. This requires an accurate determination of the length of the pendulum as well as the time of oscillation, and also necessitates the measure of the vibratory movement of the stand on which the pendulum swings. The English content themselves with relative measures from one station to another and simply compare the forces of gravity, by counting the number of oscillations made by the same pendulum in the two places. They determine absolute gravity only at a base station. It is evident that the latter method is immeasurably superior in point of economy, and we may say that it can be made to yield results fully equal in accuracy to those of its rival school. Moreover the differential method has the great advantage of eliminating all those sources of error that are practically the same for each station.

General Results of Pendulum Work.

Knowing now which method best suits our purpose a still further question arises. How accurately shall we do the work? Certainly not as accurately as we can. That would be bad economy from every point of view. Nothing is gained by measuring the force of gravity to its 1/100000th part to determine local deflections when these variations themselves are several times as great. No fact is more certainly demonstrated than that certain places on the earth's surface present variations of the force of gravity quite exceeding anything to be expected either from the amount or density of the adjacent matter. These anomalies in many cases baffle all attempts to classify them, but one general result seems to be that mountains are light and islands are heavy. Some of the first, if not the very first pendulum observations made, gave the strange result that the Andes in Equador are not much heavier than water. Foster's celebrated series on Green Mountain gave a result indicating that this volcanic formation is about twice as heavy as cork. The sacred mountain in Japan has given a similar result, namely, that the mountain is lighter than would be indicated by its volume and density. Haleakala in the Hawaiian Islands seems to be of the same mean density as the rocks on its surface. One observer has even gone as far as to say that the Alleghany Mountains in Pennsylvania weigh less than nothing, meaning by this, that if gravity at the summit be corrected for elevation, the result is not more than gravity at the base, showing the downward attraction of the mountain to be practically insignificant. If we glance at a few island stations, gravity is found to be mostly in excess of what it ought to be. The most striking examples are Fernando, St. Helena, Ascension, Minecoy, Isle of France, Bonin, Maui and

Caroline Island. At all of these gravity is more than theory demands, and they are generally islands situated in a deep sea and considerably removed from continental masses. This excess has in many cases been shown to be more than can be due to the extra attraction of the water, so that there must be a real increase in density under the ocean bed. We may therefore look to pendulum observations for information in regard to the internal structure of the earth. Deviations from the law of uniform density may be greater than has hitherto been supposed. Two well known authorities on the subject have already expressed the belief that the center of gravity of the earth does not lie at the center of figure, but is to be found inside the hemisphere that is under the Pacific Ocean. We have an example of this excessive seaward attraction in India. When a chain of triangles was thrown across the peninsula of Hindoostan from the Bay of Bengal to the Arabian Sea, it was expected that the astronomical amplitude of the arc would exceed the geodetic amplitude; in other words that that the plumb-line would be deflected towards the high table lands over which the arc was measured. The contrary was found to be the case. The seaward attraction was more than that from the continent, and an identical result followed from two independent arcs. We may therefore accept the fact as proven, that the attraction of continental masses is in some way partially compensated by a deficiency of density in the immediately underlying strata. It may be asked what relation this defect of gravity on high table lands, as revealed by the pendulum, bears to the horizontal attraction as brought out by a comparison of astronomical and geodetic latitudes. The Himalayan attraction on the plumb line at Dehra, a point less than 50 miles distant and with an elevation of 2000 feet, is 1/5000th part of the total force of gravity at the earth's surface, whereas the defect of gravity at or near the summit is 1/2000th part of the total force. This somewhat strange result may be explained in two ways. First the deflection at Dehra may be produced by matter lying between this place and the summit; or the great plateau of Thibet with an average elevation of 15,000 feet may exert the attractive influence on Dehra, and the strata immediately under the pendulum station at the summit may possess a very small density. This last view would seem to be supported by the fact that there is a deflection in azimuth as well as in latitude at Dehra.

The condensation theory assumes that all pyramids of matter having their vertices at the center of the earth and having equal bases, contain equal amounts of matter, and that the vertical attraction at any point on an elevated plateau is equal to that obtaining at a point on the sea-level immediately under it,

if we imagine the plateau to be compressed down to that level. An equipotential surface would be several hundred meters below the surface of the actual ocean, and as much above the mean continental surface.

The Earth's Geometrical Figure.

It is probably demanding too much at present, to ask the acceptance of the tetrahedral theory of the earth's figure, but in connection with gravity work allow me to call attention to some points of the argument. It is well known that gravity is in excess at island stations. If we admit the tetrahedral system, these ocean areas are really nearer the center of the earth, and hence should show increased gravity while the continental masses would tend to increase the effect still further by elevating the surface of the sea in their immediate vicinity. It has been shown that the attraction of the Himalayas would elevate the surface of the ocean immediately under them by nearly 1000 feet. This would be equivalent to increasing the distance from the earth's center by 1/16,000th part of itself and gravity would be diminished by twice this amount, which is a very appreciable quantity. Besides nothing is more in accordance with the action of physical laws than that the earth is contracting in approximately a tetrahedral form. Given a collapsing homogeneous spherical envelope, it will assume that regular shape which most readily disposes of the excess of its surfaces dimensions, or in other words the shape that most easily relieves the tangential strains; for while the sphere is of all geometrical bodies, the one with a minimum surface for a given capacity, the tetrahedron gives a maximum surface for the same condition. Experiments on iron tubes, on gas bubbles rising in water and on rubber balloons, all tend to bear out the assumption that a homogeneous sphere tends to contract into a tetrahedron.

These ideas regarding the shrinking nucleus of our globe and the consequent form assumed by the surface are not by any means new. They have long since been formulated by Green and have found favor in France. Mr. Green has even gone so far as to study the land and water areas of the globe, and has succeeded in finding a close correspondence between the actual features and those required by the theory. Africa and Europe are considered as one continent, and a depression is assumed between Europe and Asia. In point of fact there was a time when a glacial sea existed along the Siberian frontier and communicated with the Caspian waters. Admitting also a polar sea and an antarctic continent, both of which seem highly probable; there seem to be reasons for the acceptance

of the theory. Then again, it seems quite well established that our present continental forms are very old, which would indicate that whatever form the contracting earth may be taking, it has been gradually settling into this shape for many millions of years. No reference is made at present to changes on the earth's surface, consequent upon outside conditions. The changes in the eccentricity of the orbit which has its greatest value at intervals of about 2,500,000 years certainly produce vast changes in the distribution of matter, from the accumulation of ice and snow, and from the shifting of the ocean currents; but these are purely surface phenomena, and do not probably affect the permanent shape of the contracting nucleus. Besides, any change produced at a time when the eccentricity was at a maximum, would be counterbalanced when the next minimum occurred somewhat more than a million years later. But the earth's contraction goes on indefinitely throughout all time.

This brings us to a consideration of

The Earth's mean density.

The pendulum has recently been employed in such determination.

It is well known that during the early part of this century Dr. Hutton conceived the idea of determining this constant by comparing the attraction of the earth with that of a mountain of known dimensions. The method of course rests on the assumption that the volume of the mountain is a determinable quantity and also that the mountain is solid. Latitude observations were made on the north and south flanks and the results were compared with the actual differences of latitude obtained by connecting the points by triangulation. This way of getting the earth's mean density has been employed in a number of cases since Dr. Hutton's time and always with approximately the same result. It is evident now that if we have a means of getting a value for the density of the mountain that is independent of the latitude observations we get a rigorous check on the final result. This modification of the problem was applied with entire success in the Sandwich Islands in 1887; and not only was the mountain much larger and higher than in Dr. Hutton's work, but its form was much more accurately known. The entire island of Maui rises to an elevation of 10,000 feet and has on its summit the crater of Haleakala, which is twenty miles in circumference and half a mile deep The whole mountain has been contoured from the sea to the summit giving differences of elevation for every 500 feet. This gave a means of calculating with a high degree of

precision the disturbing effect of this huge mass of lava on a plumb line suspended north or south of it. But the mass of the mountain enters as one of the unknown quantities. This quantity was determined by measuring the force of gravity at the sea-level and at the highest practicable point by means of the pendulum. Knowing the mass of the mountain and therefore its mean density, its attraction at any given point is easily deduced. Now the result of the work was this: the pendulum observations showed that the mean density of the mountain was very nearly one-half that of the earth's mean density, that is, that the island is a little more than two and one half times as heavy as water. This value would lead us to expect, at the point selected on the south shore, a disturbing effect on our star observations of 28″. When the two points on the north and south sides of the island were connected by triangulation a discrepancy of 29″ was brought out. The agreement between the results obtained by two independent methods is so close as to give us considerable confidence in the astronomical and geodetic parts of the work as well as in the measurement of the force of gravity at the upper and lower station. Besides this, rock specimens were secured from many parts of the island at different elevations. Their densities were carefully determined at the bureau of weights and measures in the Coast Survey Office. When a mean value was taken we arrived at the result that the mean density of the mountain is somewhat more than that of the rocks found on its surface. This is contrary to the result generally obtained on mountains and high table lands; and it is notably in opposition to determinations on continental mountains. But let us remember in this connection that the sea level in the neighborhood of continents may be considerably disturbed by the attraction of the land, and that a single mountain in the middle of a deep sea would have practically no influence in elevating the surface of the ocean. In point of fact the island of Maui could not elevate the surface of sea around it by more than ten feet—a quantity easily neglected in this investigation.

One word about the correction for

Continental attraction.

We know that on a sphere at rest attraction varies inversely as the square of the distance from the center, but in the case of a rotating spheroid this assertion is not true. The actual diminution of gravity from the pole to the equator is about $\frac{1}{200}$th part of itself—this is in part due to the centrifugal force in consequence of the earth's rotation and in part to the spheroidal shape into which the earth has been thrown by this rotation. Bouguer was the first to call attention to the fact

that besides the influences just mentioned some allowance should be made for the matter lying above the sea level; and his formula, based on the relation between the mean density of the earth and that of the crust, is still employed. The propriety of this method of treatment has, however, several times been questioned. In the first place, because observation seems to show mountains and table lands to be much too light, and in the next place, because the excess of gravity noticed at island stations is very nearly accounted for by making a correction for the downward attraction of the sea. Of course we meet with many anomalies in gravity determinations, but it would seem better in the present stage of the subject to make some disposal of the influence of the continents. The estimate may indeed be a rough one, afterwards to be modified as more data accumulates, but in the light of our present knowledge we may apply the corrections as follows: at a station say 1900 feet above sea level a seconds pendulum will lose eight seconds daily on account of its elevation, and it will be accelerated in the same time by three seconds from the influence of the mountain matter, so that both effects together would cause a loss of five seconds per day. This rule of course does not hold strictly at great elevations; nevertheless it was found approximately true in the Sandwich Islands where the pendulum was carried to an elevation of about 10,000 feet. Here we had a daily loss of 41^s from elevation and an acceleration of 13^s from the mountain attraction giving a total loss of 28^s daily. This agrees tolerably with the ratio above stated.

Changes of Latitude.

Closely connected with the variations of the force of gravity are the changes of terrestrial latitudes. Whether the earth's crust is floating on the plastic or semi-plastic nucleus, and really shifts its position with reference to the axis of rotation, or whether latitudes change by reason of the moving of quantities of water and air, it is now impossible to say. Within the last year it has been abundantly demonstrated that latitudes may have an annual variation of a considerable fraction of a second. The International Geodetic Association of Europe has taken the matter up and will send an observer to Honolulu in order that simultaneous observations may be made on opposite sides of the earth. The U. S. Coast and Geodetic Survey has been asked to coöperate and will also send an officer to the Sandwich Islands, besides observing continuously at Washington, San Francisco and other points. The Royal Observatory at the Cape of Good Hope will engage in the work and probably other permanent stations may be established in the southern hemisphere.

The outcome of all this will be that when observations from opposite sides of the earth are compared we shall be able to decide whether the axis of the earth actually shifts its position, or whether changes of latitudes are due to transfers of molten matter below the crust.

If the results at Berlin and Honolulu show opposite phases at the same time, we should expect the latitude to be stationary at Washington, because this point is one-quarter way around the globe, or midway between the other two stations. The conclusion from this would be that there is a real motion of the pole and not a transfer of material inside the earth.

There is a decided maximum and minimum within twelve months with a larger maximum and minimum in a five-year period. In addition to this the Greenwich observations show a long period of inequality extending over sixty years. The cause of the short period movements has been ascribed to the interference of the motion of the axis of inertia with that of the ten-monthly period of the axis of rotation. It can certainly be assumed that the sun and moon produce atmospheric tidal effects changing with the seasons, and it is also known that the shifting of a mass of water covering $\frac{1}{10}$ the earth's surface and being 0·10 meter thick would cause the axis to move $0''\cdot16$ —a quantity which is quite measurable in all latitude work of precision. As this depth of water corresponds to an atmospheric pressure of about 0·007 meters it is evident that extensive changes in the density of the air may produce a slight change in the position of the earth's axis; so that it would seem well worth while to measure the force of gravity from time to time at the same place in order to detect changes that would most probably be produced by changes of latitude.

Practical Methods.

When we come to the actual field work, again several methods present themselves for our consideration. The ultimate end of the observations is to find how long it takes the pendulum to make an oscillation at a given temperature and atmospheric pressure. Most of the slight corrections necessary to reduce the different experiments to the same conditions, and thus make them comparable, may for our present purpose be passed over in silence. The reduction to an infinitely small arc involving only simple geometrical considerations is easily disposed of. The influence of the temperature and density of the air requires special treatment, and has been made the subject of careful study by all pendulum observers. The air not only has a buoyant effect on the oscillating body, but by reason of its viscosity adheres to the pendulum and is drawn along

after it. The atmospheric effect has been treated in one system of equations, where the unknown quantities vary directly as certain powers of the pressure and inversely as powers of the temperature. All these corrections are of much more importance in absolute determinations than in relative ones. This brings us to the different methods of observing.

Two methods have been chiefly followed. First by noting coincidences between the gravity or experimental pendulum, and the pendulum of a clock set up a short distance away. This is by far the most easy and accurate method of getting the length of one oscillation of the gravity pendulum. The second method is by registering on a chronograph the passage of the pendulum across a fixed point of reference. Forty of these transits suffice to give a mean value, which carries the accuracy of this part of the operation far beyond that attained in deducing some of the other necessary corrections. The probable error of the mean of a chronographic set is only 0·003 of a second and when this is divided by 15000, the number of oscillations in one swing, we get an accuracy beyond one millionth of a second. This is all that can be desired, but the method of coincidences is still more accurate while it is much less difficult to observe. We may commit an error of many seconds in the time of a coincidence without vitiating the result. The distinctive feature of the last method is this: when we commit an error of one second in noting the time, we do not change the value of one oscillation in the ratio of this error to the length of the swing, because both pendulums are moving along together. An error in the time of coincidence only means that the result will be in error by an amount equal to the ratio, one has gained on the other in the short time between the true coincidence and the one noted, multiplied by the ratio of the error to the whole period. To illustrate by a special case, suppose that in 600 oscillations of the clock pendulum, the gravity pendulum loses two oscillations, and suppose that the coincidence was erroneously noted after 602 oscillations had been made instead of 600. This error is 1/300th of the interval, but far from introducing an error of 1/300 in the length of one oscillation the error is only 1/300th of the ratio of the gain of one pendulum on the other, that is 1/300 of 1/300 or say 0·00001. It is thus seen that the accuracy of the result is a function of the length of time between two coincidences, and that the longer the interval the more accurate will the result be given. One might suppose therefore that the coincidence period might be indefinitely long, but there are economic considerations bearing on the question. For instance we cannot afford to wait very long for the coincidence because this would entail too much loss of time. Therefore in

general intervals should be chosen which are not longer than are necessary to secure the desired accuracy, and the swing should be repeated in order to eliminate accidental errors.

In the chronographic method, an error in the determination of the interval between the first and last observation is simply divided by the number of oscillations in the interval, and therefore affects the result much more than by the coincidence method.

There have been many ways devised for noting these coincidences. I shall first call attention to a few of the older methods which leave nothing to be desired as to accuracy, but which have been superseded by an elegant arrangement devised by Professor Mendenhall and which, while giving all the accuracy needed makes the observation both simple and easy. First we had a piece of card-board fastened to the clock pendulum. This card-board had on its surface a number of spots which were seen to disappear at each coincidence of phase in the motion. The time of disappearance and reappearance were noted and the mean taken for the true coincidence. For increased accuracy a number of spots were observed, and for convenience in taking the time the spots were arranged in the form of a curve, resembling a hyperbolic spiral, which would give about equal times between successive disappearances for all amplitudes of oscillation. This method was modified in the case of the Peirce pendulums by placing a scale on the clock pendulum and a small needle point on the gravity one. This last procedure is in direct violation of the whole theory of differential gravity measures, namely, that the pendulum must undergo no change from one station to another. However, as the mass added is exceedingly small, and besides is placed very near the center of oscillation, where theoretically it would have no influence whatever on the time of vibration, the method is considered admissible.

Both the preceding ways are applicable only to two moving pendulums and suppose them to be of equal length. The methods depend on sight alone. Coincidences have also been observed by the eye and ear method, by comparing the beat of an ordinary sounder used in telegraphing, with the transit of a pendulum across the vertical thread of a telescope. This avoids carrying a clock from station to station, a break circuit chronometer furnishing the beat every second. The method has not been very extensively employed, as it requires considerable practice on the part of the observer.

We now come to the last way, and which is believed to be in many respects the best: and here we have to do, not with two pendulums, beating approximate seconds, but with a single pendulum beating half seconds, whose coincidence must be

noted with a chronometer beating whole seconds. This required the invention of an entirely new kind of apparatus. It was evident some means must be had by which the coincidence could be noted optically. For this purpose the chronometer was made to open every second the armature of a relay to which was attached an upright thin piece of metal. This metal was perforated by a thin slit which by the movement of the armature passed before a fixed slit a short distance in front of it, so that a light suitably disposed gave a flash every time the chronometer broke the electric current. The apparatus was placed about ten feet from the pendulum, and was so adjusted that the beam of light from the slit fell on two mirrors, one of which was on the pendulum and one near by it. The former was therefore movable by the motion of the pendulum while the latter was stationary. From these mirrors the beam of light was reflected back into the observer's telescope. When the pendulum was at rest, the observer saw two illuminated slits every second in the field of view, but with the pendulum in motion the flash that came from the pendulum mirror could only be seen when the pendulum happened to be near its equilibrium point. It is evident that if the pendulum makes exactly two oscillations for every second of the chronometer, the relation of the images will not change, and we shall see a double flash every second in the middle of the field of view. But if the time of oscillation of the pendulum is slightly different from a half second, it will not return quite to its former position by the time the next flash occurs, and we shall have its image displaced with reference to the one from the fixed mirror. Here then we have two necessary conditions for the appearance of the flash from the pendulum. First the chronometer must open the slit, and second, the pendulum at this instant, which has a duration of about 1/100th of a second, must be in such a position that the image of the slit will be reflected back into the observer's telescope. We only need now a point of reference to which the motion of the movable image may be referred. This is furnished by the flash reflected back from the stationary mirror, and as the image from the pendulum is seen to pass slowly across the field of view, the time is noted when the two images coincide. For pendulum A, the time of oscillation exceeded half a second by 0·0066 seconds, which gave a coincidence interval of $6^m\ 15^s$. This was adopted for the other pendulums. Inasmuch as it was contemplated to use these instruments in all parts of the United States and at all altitudes, it was necessary to consider the effect of a change of latitude and elevation on the coincidence interval, because a period might be chosen at Washington, which would make the intervals too long for conven-

ience on the Canada frontier and too short for accuracy on the Gulf of Mexico. A compromise was made between the several conditions and the above mentioned interval of $6^m\ 15^s$ chosen. It so happens that the effect on the coincidence period is about the same, whether we pass from the latitude of Washington to the Gulf of Mexico, or carry the pendulum from the sea level to the top of Pike's Peak; the height in the latter case having the same effect as the change in latitude in the former.

In the new work proposed by the Coast and Geodetic Survey all experiments are to be made at a given atmospheric pressure. This will be about a mean value of those actually found in practice. Air will therefore be forced into the chamber at mountain stations, and pumped out at the lower ones. It being decided to swing the pendulums in an enclosed space, the interesting question came up, how close can the pendulum be placed to the walls of the chamber, without influencing the time of oscillation; or in other words, how small can we make the box and still have the pendulum swing just as it would in the open air. Experiments were made with boxes of different sizes and shapes. The result generally stated was that the effect of the sides of the chamber only began to be felt when they were within about one inch of the moving body, and that what is known as "skin friction" is more effective than impact friction. That is to say that proximity of the wall to the side of the pendulum has more influence than nearness in front or back of it. The viscosity of the air is indeed an important factor in the investigation, as it is well known that besides the buoyant effect of the air it adheres to the pendulum and is drawn along with it. This influence has been studied both theoretically and practically by Stokes, Green, Peirce and others, and has furnished some fine examples of mathematical analysis.

The temperature of the pendulum is found by means of another pendulum of exactly the same shape, size and material, except that the knife edge is of hard rubber instead of agate. This auxiliary pendulum is suspended inside the receiver. To it is attached a thermometer, whose bulb is encased in filings of the metal imbedded in the stem of the temperature pendulum. The presence of this auxillary instrument has no appreciable effect on the period of the swinging pendulum, either from air disturbance or from the vibratory movement of the support. This fact was carefully determined by experiment.

In the last cruise of the U. S. Man-of-War Pensacola, an officer of the Coast and Geodetic Survey was sent to determine the force of gravity at some stations in Africa, and on some islands of the North and South Atlantic. The computations have just been completed, and the results are in conformity

with the theories exposed in the body of this article. The stations on continents whether in Africa or America show a defect of several oscillations per day in the movement of the pendulum; whereas those islands that are surrounded by a deep sea and considerably removed from continental masses invariably give an excess of gravity. The Barbados, in the West Indies, has about a normal value, which is just what we expect since it is neither surrounded by a deep sea, nor is it very near the South American Continent. Observations were made at St. Helena and Ascension both at the sea level and on the summit of the mountain. The work shows that the mean density of the whole island in both cases is considerably less than that of the rocks found on the surface, so that the attraction of the mountain must in some way be compensated for by the internal structure or composition of its material.

ART. LIV.—*On the Post-Glacial History of the Hudson River Valley;* by FREDERICK J. H. MERRILL.

FROM the post-Glacial deposits in the Hudson River valley may be derived much information as to the conditions prevailing therein subsequent to the retreat from its vicinity of the continental glacier.

These deposits are of two general types: estuary formations of stratified clay and fine sand deposited in still water, and cross-bedded delta deposits of coarser material. They fringe the river shores in terraces between New York and Albany and indicate a long period of submergence, their present altitude above tide showing that the land has been elevated with respect to sea-level since their formation. Their materials were apparently brought into the estuary by tributary streams which dropped the coarser particles near their mouths, while the finer rock flour was carried on in a state of suspension, and was finally precipitated to form beds of clay.

From Albany westward spreads an alluvial formation which attains at Schenectady an altitude of about 340 feet and extends through the Mohawk Valley in terraces which rise in altitude till they merge in the elevated beach plain of Lake Ontario at Rome about 405 feet above tide level. The origin of these terraces has not yet been determined. According to Mr. G. K. Gilbert the raised beach at Rome is that of a lake dammed by ice in the St. Lawrence Valley and flowing out into the Mohawk Valley, which carries its drainage into the Hudson estuary. According to this view the alluvial plain at Schenec-

tady is the Mohawk delta, and the terraces of the Mohawk valley are stream terraces.

Recently Mr. J. W. Spencer* has advocated the hypothesis that the raised beaches of the Ontario basin were formed at sea-level. In this case the Mohawk valley terraces would be estuary terraces homologous with those of the Hudson valley. An examination of these terraces is necessary to determine the point at issue.

The delta of the Hudson River torrent has not yet been studied by the writer, but it will probably be found in the neighborhood of Sandy Hill. A general description of the estuary deposits of the Champlain Period in this region has been given by Professor W. W. Mather (Geol. 1st Dist. N. Y., pp. 148, 149).

Between Poughkeepsie and New York the following streams have formed extensive delta deposits: Wappinger's Creek near New Hamburg, Fishkill Creek, Quassaic Creek at Newburgh, Moodna River at Cornwall, Indian Creek at Cold Spring, Peek's Kill, Cedar Pond Brook and Minisceong Creek at Haverstraw, Croton River, Pocantico River at Tarrytown, Sawmill River at Yonkers and Tibbit's Brook at Van Courtlandt Park, New York City.

The deposits of Peek's Kill or Annsville Cove, as it is now called, are of considerable interest. These names designate the basin which receives the waters of Annsville Creek, Sprout Brook, and Peekskill Hollow Creek, the last of which carries the drainage of several long and deep valleys trending to the northeast through Putnam County. About the margin of the basin are several terraces about 120 feet high showing characteristic delta structure and on the west bank of the Hudson opposite the village of Peekskill and immediately south of Jones' Point is a terrace of coarse gravel which has the same altitude as those on the east bank and which was, at one time, regarded by the writer as a portion of the Peek's Kill delta deposit. The coarseness of its material, however, would seem to preclude the possibility of this and to suggest that it originated as a moraine or a kame and was subsequently terraced in the waters of the estuary. On the flank of Crow's Nest Mountain near West Point the base of the terrace exposed in the railroad cutting is formed of bowlders of considerable size and it is suggested by Mr. G. K. Gilbert that this deposit was formed by a lobe of the retreating glacier.

The estuary deposits of the Hudson River at New York indicate a post-Glacial depression of more than 70 feet. The terraces which border the west shore of Manhattan Island from

* This Journal, vol. xl, p. 443 *et seq.*

75th street northward have a maximum height of 70 to 75 feet and on the New Jersey shore of the river, terraces of about the same altitude occur at frequent intervals. One of the most prominent of these is at Fort Lee, south of the steamboat landing. The surface material of these terraces is a fine sand or silt easily transported by the wind. It is evidently not a material which could be laid down in running water, for it would be carried in suspension by a river current and could only be precipitated in the still water of an estuary. North of New York City the altitudes of the terraces have been determined at a few points as follows:

Mouth of Croton River	100 feet.
Peekskill	120 "
West Point	180 "
Fishkill	210 "
Schenectady	340 "

A detailed measurement of the terrace altitudes between Fishkill and Schenectady has not yet been made.

On the Long Island Sound shore of Westchester County, N. Y., the till which covers the metamorphic rocks has apparently been levelled off by wave action at an altitude of 75 to 85 feet. Plains of this character occur at frequent intervals, being separated by river valleys, and were probably formed during the depression which occasioned the estuary deposits of the Hudson River valley. These plains are composed of a modified till, obscurely stratified, somewhat sandy near the surface and comparatively free from bowlders, but unaltered bowlder clay or till occurs at a few feet below their surface. On one of the most extensive of them the village of New Rochelle has been built.

On Staten Island and western Long Island alluvial plains of stratified material rise gently from the ocean shore to the margin of the moraine, terminating at an altitude of about 80 feet, and, though no continuous shore-line is to be found, the plains are referred provisionally to the same period as the estuary deposits a few miles north.

From the evidence quoted the amount of the post-glacial depression at New York is estimated at about 80 feet. Whether this was subsequent to a greater depression of post-glacial date remains to be determined.

In the estuary which occupied the Hudson River valley during the depression, there was deposited a great depth of plastic clay, evidently a sediment of aluminous rock flour produced by glacial attrition, and held in suspension by the post-glacial streams, and resting upon this clay, is a deposit of fine stratified sand. This bipartite character of the Hudson River estuary

formation suggests that two distinct conditions prevailed during the time of its deposition. The clay represents a period of still water deposition when little or no siliceous material was washed into the basin, while the overlying stratified sand was evidently deposited at a time when much siliceous matter was carried in by the tributaries.

The causes of this differentiation are not clearly manifest. If there were good evidence to show that, at the close of the ice-period, there had been a greater submergence of the continental margin than that proven by the delta deposits above mentioned, the hypothesis might be advanced that during this greater subsidence there was but little of the land surface exposed above sea-level in the vicinity of this estuary and consequently but little surface drainage. The larger tributaries fed by waters from the melting glacier would then bear into the estuary a large quantity of rock flour which would be held in suspension for a time and would finally be deposited in the deeper water as clay. As the land rose from its submergence, however, a larger area would be exposed to surface drainage and would yield in immediate proximity to the basin, an increasing amount of siliceous matter which would be deposited over the clay and constitute the upper member of the estuary formation.

It remains for future investigation to determine the total amount of submergence in this region cotemporary with the last advance of the ice sheet and subsequent to its retreat.

The records of ocean wave action are in many cases different from those of the extinct Quaternary lakes and not so easy to recognize. It is not always possible to decide a question of submergence by the presence or absence of a distinct shore-line. On a lake shore wave action tends to cut in an horizontal plane and the result is a series of terraces or a beach plane associated with shore drift and littoral deposits in various phases. When ocean waves act upon a shore there may be two cases:

1. The land may be at rest. In this case the result will be the same as on the shore of a lake which maintains its level for a comparatively long time.

2. The land may be rising or subsiding with respect to sea-level. In this case the plane of erosion will be a resultant of two planar forces: *a*, the wave force which operates in an horizontal plane; *b*, the force of elevation or depression which acts in a vertical plane and subjects to the former successively lower or higher portions of the land margin. According to the relation of these forces or the relation of the rate of land movement to the rate of wave cutting the plane of erosion will vary in its inclination. As the cutting rate relatively increases

the plane of erosion approximates to horizontality, and when it becomes infinitely great the plane of erosion will become a base-level. As the cutting rate relatively diminishes, the plane of erosion will become more and more inclined to the base-level and will approach verticality. When the cutting rate becomes infinitely small with respect to the rate of land movement the plane of erosion becomes vertical. In this case a vertical rock face would not lose its verticality by the erosion nor would the slope of the land surface be altered except through variations in the resistance of the rock acted upon.

The degree in which the eroded land surface would approximate to an oblique or vertical plane of erosion would depend upon the previous configuration of that surface. In order to completely discuss this question it would be necessary to consider a large number of incidental factors which might divert the plane of erosion from its theoretic position and prevent the eroded land surface from coinciding with it, but this completeness is unnecessary for the present purpose which is simply to point out the fact that a land surface in process of subsidence or emergence may be subjected to wave action without being incised with distinct shore lines, and also that *wave action may produce an inclined plane as well as a terrace or a base-level.*

It is therefore evident that submergence would not leave a deeply cut shore-line as its record unless the rates of land movement and wave cutting were so adjusted as to permit of it. In fact, no very distinctly cut shore lines are to be found on the drift about New York even at an altitude corresponding with that of the Hudson estuary deposits. Apart from the still water deposits the 80 foot post-Glacial depression about New York can only be traced by change of surface slope and material at this level. Even these two varieties of evidence are not always co-existent.

There are in Westchester County and on Long Island indications of wave action on the glacial drift at altitudes of 150 to 180 feet, it remains to be determined whether they are reliable.

The present condition of the Quaternary deposits in the Hudson valley is indicative of fluviatile erosion in post-Champlain time. The estuary deposits and deltas have been eroded and truncated until but a narrow fringe is left of formations which once extended far across the valley or filled it, and the water in the channel of the river has now a depth varying from 50 feet in the shallower portions to 180 feet in the deepest parts.

The delta deposits have also been subjected to the erosion of the streams which formed them and which developed cutting power as the land rose from its submergence. This erosion removed a large portion of the deposits and excavated chan-

nels through them below present tide-level. The mouths of the tributary streams are now generally silted up and the process of filling seems to be going on at present. It seems indisputable that the brick clay deposits once filled the entire valley up to a certain level, and that the present depth of the channel of the Hudson is due to the erosion of the still water deposits by a river current. It is also probable that in the narrow gorge of the Highlands some of the deltas filled the valley, but this point has not been fully determined.

Between Poughkeepsie and Albany at many points near the water's edge are steep, unglaciated rock surfaces much fresher in appearance than the glaciated surfaces upon which the Champlain deposits rest. These may be the result of river erosion subsequent to the formation of the terraces.

The evidences of fluviatile erosion enumerated suggest a rapid flow of water down the Hudson valley in the late Quaternary. Such a flow doubtless began when the valley rose from its submergence. With these evidences of erosion may be correlated the gorge of the Narrows at the entrance of New York harbor. This is a gap in the terminal moraine about 240 feet deep and one mile wide at tide-level and there is no evidence that it could have resulted from non-deposition of the drift. The bottom of the present channel has a maximum depth of 100 feet below tide-level.

It seems highly improbable that the present navigable channel of the Hudson could have been excavated to its present depth in the Champlain deposits by any agency except that of a river current,* and taking the maximum depth of the channel in the Narrows as an example of this erosion we have the amount of post-Champlain subsidence suggested as about 100 feet in the vicinity of New York.

Observations on the coast of New Jersey and Long Island have well established the fact of recent subsidence which can be measured to the extent of 20 feet, by submerged tree stumps. The evidences of fluviatile erosion in the Hudson valley suggest that this may be not more than one-fifth of the total amount.

From the evidence quoted it may be stated provisionally that after the retreat of the continental glacier from the Hudson River valley, the land stood for a long time at a lower level than at present. What the maximum of depression amounted to is not known but in the vicinity of Albany the minimum depression amounted to about 340 feet and at New York to about 80 feet. Next occurred a gradual elevation of the land amounting to about 180 feet at New York and at Albany to an amount undetermined, but probably not less than

* See J. D. Dana, this Journal, vol. xl, p. 435.

350 feet and perhaps 400 feet or more. During this elevation occurred extensive erosion of the Champlain estuary deposits in the river valley and subsequently followed a depression which has amounted to about 100 feet at New York and which is apparently continuing at the present day.

As the land rose from its 80 foot depression at New York there seems to have been a brief period of less rapid elevation during which a second series of estuary terraces and alluvial plains were formed which now stand about 25 feet above tide-level. These have been recognized on Staten Island by Dr. N. L. Britton and may be seen on the Harlem River near Fordham Heights and at various points on the Long Island Sound shore of Westchester County.

Art. LV.—*On Alunite and Diaspore from the Rosita Hills, Colorado;* by Whitman Cross.

The occurrences to be described in this article lie between the mining towns of Silver Cliff and Rosita, in Custer County, Colorado. They were discovered while studying the geology of this region, under the direction of Mr. S. F. Emmons, preliminary to a report which will appear as a monograph of the U. S. Geological Survey. In order that the geological interest attaching to the occurrences may be fully understood a general sketch of the local geology will be given.

I. *Geological Sketch of the Rosita Hills.*

The name Rosita Hills has been applied in the course of this work to a small group of rounded hills on the eastern slope of the great Wet Mountain Valley, which lies between the Sangre de Cristo and Wet Mountain [or Greenhorn] ranges, at a point south of the Grand Cañon of the Arkansas River. They cover an area whose dimensions are about five miles north and south, by four east and west, in which are small cones and smooth-sloped ridges, whose absolute elevations vary from 8,900 to 9,700 feet above sea-level, while the western and lower base of the hills is at 8,500 feet. The Rosita Hills are made up of volcanic rocks, while Archæan schists surround them on all sides and constitute the floor upon which they rest, there being no sedimentary formations in the vicinity, excepting local tufa beds. Upon the Hayden Geological map of Colorado, Dr. F. M. Endlich being responsible for this portion, the Rosita Hills are included in a much larger area of eruptive rock [" trachoreite," Endlich.], represented as extending along the base of the Wet Mountains. In this connection it may

not be out of place to state, for the information of those who have no grounds upon which to establish a personal opinion, that the term "trachoreite" of Endlich has no petrographical signification whatever. Almost all varieties of volcanic rocks known in Colorado—a long series—may be found prominently developed in areas mapped as "trachoreite" by Dr. Endlich.

The Rosita Hills are remarkable, when compared with other volcanic areas of the West, for the number of eruptions and the variety of products in so limited a district. Volcanic activity began, as indicated by the products seen, with an eruption of an andesite carrying hornblende and biotite. The action was explosive, for the product is wholly fragmental, consisting of mud, tufa, and breccia, now exposed in very irregular relations. The vent is not known, and probably lies under some later flow. After erosion of the soft materials of the first period came two massive andesite outbreaks, one more basic, the other more acid, than the first. These overlap the earlier breccia on the north and south respectively, and form prominent cones and ridges.

Succeeding these andesitic eruptions came a series of rhyolitic outbursts. The earlier ones were violently explosive as shown by the agglomerate filling some of the vents, while the later ones were more quiet, producing massive rocks, seen in many short dikes cutting all the earlier andesites and the rhyolitic agglomerate, and in thin sheets on all flanks of the hills. Following the rhyolite came another andesitic magma, welling out through long fissures which cut all earlier rocks. Surface masses of the same rock are seen. It is a mica-augite andesite, with some free silica. The last important eruption produced a rock carrying a very slight excess of silica and having the characteristic structure and mineral composition of a trachyte. This magma came up through fissures some of which are nearly three miles long, and clearly traverse every rock that has been mentioned, excepting the dacite, which does not lie in their course. The later rocks of this series are in many places very fresh, while the older andesites are as a rule far gone in decomposition. This general decay is mainly due to thermal waters coursing through innumerable fissures. In these decomposed areas are many small, metal-bearing mineral veins.

The area whose volcanic history has thus been outlined is regarded by the writer as practically a volcano, whose phases were of very different character at different times. Four out of six important outbreaks produced massive rocks and but two were of the explosive character more commonly seen in true volcanoes. But the integral nature of the whole is evident from the study of the mutual relationships of the

rock masses. As a further proof that typical volcanic action has occurred here stand the masses of decomposed rhyolite which are to be described, for they can only be explained on the supposition that the rhyolitic outburst, known to have been of violently explosive character, was followed by a period of sulphurous gaseous exhalations whose products are identical with those of well known volcanic regions. There were two vents in particular which thus became true solfataras, and about them the rhyolite has suffered change into a rock-mass affording unusual resistance to atmospheric agencies and now forming rugged cliffs and projecting outcrops in a region of prevailingly gentle slopes and rounded contours. These two localities are in Democrat Hill and Mount Robinson, both situated in the inner part of the group of the Rosita Hills.

II. *The alunite rock of Democrat Hill.*

Democrat Hill is situated in the center of the Rosita Hills and in the acute angle between two gulches. It is of general rounded shape at the base, with a diameter of 1,500 feet and rises only 400 feet. On the north, or opposite the forks of the gulch, it joins on to a long ridge of andesite, and indeed all to the north is andesite, excepting later dike rocks, while to the south the prevalent rock is rhyolite, chiefly in the form of flows, some of which issued from the conduit below the hill.

The upper three hundred feet of Democrat Hill stands out as a rough massive knob whose projections are somewhat rounded, though split by fissures and presenting occasional cliff faces. The color is slightly reddish and the whole presents a strong resemblance to certain outcrops of massive granite. The lower hundred feet of the hill are covered by great angular blocks which have fallen from the cliffs above. A close examination of the rocks shows it to be cellular, the cavities being of irregular shape and varying in size, with a maximum diameter of several inches, and an average of about one inch. The cells are lined by rudely tabular crystals some of which are composite and all are obscured by the minute quartz crystals deposited upon them. The mass of the rock is an irregular aggregate of imperfectly tabular grains of a mineral closely resembling orthoclase in luster, hardness, and general appearance. A pronounced cleavage runs parallel to the dominant planes of the tablets. The only other constituent of the rock is quartz, which forms a very evenly and finely granular mass between the tablets, and its grains are also abundantly included in the latter. A small amount of snow-white kaolinite is sometimes seen in the cavities.

Microscopical examination of thin sections of the rock, and of cleavage flakes, shows the questionable mineral to be uniaxial,

positive, and the cleavage is parallel to the basal plane. Sections at right angles to the cleavage show stronger polarization than in feldspar, and sharp extinction parallel to the cleavage lines. The rough crystals in the cavities have the same optical characters, and the more perfect of them have a hexagonal outline caused by apparently rhombohedral planes. A chemical analysis of the average rock was made by Mr. L. G. Eakins, in the laboratory of the U. S. Geological Survey, with the following results:

			Molec. ratio.			
SiO_2	65·94					
Al_2O_3	12·95	÷	102	·127		3·26
K_2O	2·32	÷	94	·025	·044	1·13
Na_2O	1·19	÷	62	·019		
SO_3	12·47	÷	80	·156		4·
H_2O	4·47	÷	18	·248		6·36
Fe_2O_3 etc.	0·55					
	99·89					

From the above figures it is seen that the constituents of alunite are present in very nearly the molecular proportion required for that mineral, with a slight excess of water and of bases. It is quite probable that there was a small amount of kaolinite in the material analyzed. The sulphate present is slowly soluble in H_2SO_4, and after slow roasting alum can be extracted with water. This rock then is made up of quartz, two-thirds, and alunite, one-third, aside from insignificant impurities. The specimen analyzed seems to be representative of the entire upper part of the hill, though the percentages of quartz and alunite doubtless vary somewhat. Rhyolite occurs on the lower slopes about it and also underneath the summit of the hill, as shown by tunnels. A transition from rhyolite to alunite rock has not been observed at this place, but no good reason is known for doubting that rhyolite was the original rock here as at the other locality to be described. The observed limitation of the alunite rock in depth no doubt corresponds with the horizon at which sulphureted hydrogen gave rise to sulphurous acid on oxidation near the surface.

III. *The alunite-diaspore rock of Mt. Robinson.*

Mt. Robinson is the highest point of the Rosita hills, although the summit is but six hundred feet above its southern base. Its slopes are smooth, owing to the soft andesitic material beneath, but the top is a projecting ridge, a quarter of a mile long, with a cliff of from fifty to seventy-five feet in height on the south, while a growth of aspens come close up to the crest on the north. The jagged crest is fifty feet or more in width,

and is made of a hard, rough, porous rock—a decomposition product, varying locally in character, but exhibiting in few places any trace of the original rock structure. The crest represents the extreme alteration. Along the base of the summit cliffs is a plain contact between spherulitic rhyolite and andesite, and at either end of the crest the harder rock gives way to modifications showing spherulitic structure, and in one direction the body is continued for some distance as a distinct rhyolite dike, cutting through andesite.

The rock composing the rough outcrops of the summit ridge is often much like the alunite-bearing mass of Democrat hill, and is in places identical with it, but it is much less uniform in character. Certain masses are composed of bluish cellular quartz, and barite appears developed in great irregular tablets in a few spots. On the whole, alunite is not developed in so large grains as in Democrat hill, and through the numerous minute quartz grains included in it the cleavage faces are less distinct, the result being a dull whitish or slightly yellowish rock of dense texture save for small irregular pores containing kaolin or yellowish ochre. A specimen of such rock from the eastern end of the crest, whose composition cannot be made out macroscopically, but which exhibits a large amount of alunite in thin section, was analyzed by Mr. Eakins and found to contain :

		Molec. ratio.	
SiO_2	69·67		
Al_2O_3	13·72	·134	4·8
CaO	0·07		
MgO	*tr.*		
K_2O	2·44	·032	1·1
Na_2O	0·34		
SO_3	9·27	·114	4·0
H_2O	4·73	·263	9·4
	100·24		

The alkalies present are but very slightly in excess of the amount required to go with the sulphuric acid to form alunite, while there is a considerable residue of alumina and water belonging to kaolin, the presence of which is shown by the microscope. The percentage of SO_3 found corresponds to 23·96 per cent of alunite.

Toward the west end of the crest-ridge, and also near the middle, there is much of a rough, finely cellular rock consisting almost exclusively of bluish quartz and a transparent colorless mineral in irregular grains, noticeable on account of the bright luster on a very perfect cleavage plane. This mineral was at first supposed to be alunite in an unusually pure state. With

this idea in mind, a specimen of the rock taken at the west end of the summit ridge was analyzed by Mr. Eakins, with this result:

SiO_2	76·22
TiO_2	0·11
Al_2O_3	19·45
Fe_2O_3	*tr.*
CaO	*tr.*
Alk.	*tr.*
SO_3	0·29
P_2O_5	0·13
H_2O	3·82
	100·02

The alumina belonged to a mineral insoluble in most acids, and infusible in alkaline carbonates. On treatment by hydrofluoric acid, which dissolves the mineral with great difficulty, 17·79 per cent of this substance was isolated from the rock, and found to contain 84·67 per cent of Al_2O_3, with no other base, while water was present in large amount. The theoretical composition of diaspore is: Al_2O_3 85·07, H_2O 14·93 = 100. Microscopical examination of the rock in thin sections, and of cleavage flakes of the mineral in question, showed it to possess the physical and optical properties of diaspore. By reason of its high refractive index its surface relief in thin sections distinguishes it clearly from alunite, although both minerals occur in irregular grains in the rock mass and are filled by small included quartz grains.

The alunite and diaspore of this rock having been determined in the spring of 1890, the writer revisited the region in the following summer, obtained further information concerning the occurrence, and collected specimens of particular interest. On carefully examining the material from a prospect hole sunk in the quartz-diaspore rock analyzed, some specimens were found containing irregular cavities an inch or more in diameter, in which were groups of rather stout prismatic, colorless or whitish crystals, with glistening faces, though seldom transparent. The crystals have several planes in the prismatic zone, and the low terminal planes which are clearly pyramids and domes indicate the symmetry of the orthorhombic system. Much of the surface rock at this end of the dike has cavities with similar crystals which are dull white in color and clearly much decomposed, the product being a fine micaceous mineral apparently kaolin.

On the southern slope of the dike, below the summit, a few loose fragments of quartzose rock were found, with very brilliant, clear, prismatic crystals, inclined to tabular development

through the prominence of a pinacoid. While these various forms were thought to belong to a single mineral, the species was not recognized in the field. By measurements, on a small Fuess goniometer, the mineral was, however, readily identified crystallographically with diaspore, and the faces determined as follows: $\infty P \breve{\infty}$, prominent in all crystals; $\infty P\bar{2}$, the most prominent prism; ∞P, narrow; $P\bar{2}$, broad, good faces; unit pyramid, P, narrow; $P\breve{\infty}$, occasionally distinct. As this seems to be the first known occurrence of diaspore in any such connections, and also on account of the rarity of this crystallographic development, the writer requested Dr. W. H. Melville to examine the material carefully, and if the result warranted it, to present the crystallographic data, with figures, in a special article. This he kindly consented to do, and his report will be found in the paper succeeding this. A small clump of clear crystals was analyzed by Mr. Eakins with this result:

Al_2O_3	83·97
H_2O	15·43
	99·40

The results of the crystallographical and chemical examinations thus place the identity of the mineral with diaspore beyond question. Further data as to the occurrence will be given in discussing the origin of these minerals.

IV. *Alunite pseudomorphs.*

At the western base of the Rosita hills a shallow prospect shaft has been sunk in a brecciated quartzose vein matter, which is the alteration product of the country andesite on a line of fissuring. Near by is a large dike of altered rhyolite, the specimens from it which have been examined consisting of kaolin and quartz.

The shaft has long been abandoned and is inaccessible. Its dump shows mainly quartz vein matter through which some pyritiferous ore is sprinkled. One small part of the dump is made of bluish quartz breccia, the spaces between angular fragments being lined by crystals. There is first a coating of minute quartz prisms, then in some cavities larger quartzes with rough prismatic and smooth pyramidal faces. In a portion of this material there are numerous tabular crystals, and, of decidedly later age, kaolin, or ochreous limonite, in a few specimens.

The tabular crystals referred to are dull white, opaque, with rough surfaces, yet showing distinct crystal form. The faces are to be interpreted as unequally developed positive and negative rhombohedrons, combined with a dominant basal plane. In size these crystals average $0·5^{cm}$ in width, by a thickness of

$\frac{1}{2}^{mm}$. An examination with a hand lens shows that the crystals are for the most part irregular granular aggregates of some mineral possessing a distinct cleavage. This is especially clear on fractured surfaces by the irregular positions of the cleavage planes. In some of the thicker crystals, broken through the center, is seen a clear glassy kernel of a colorless mineral, and its position immediately suggests that it represents the original substance of the crystal, of which the granular aggregate about it is a pseudomorphic alteration product.

Some of these white crystals, carefully detached, but supposed to include the points of some of the quartz crystals upon which they were deposited, were given to Mr. Eakins for analysis. He found:

		Molec. ratio.	
Al_2O_3	38·91	·381	3·42
K_2O	4·03	·113	1·01
Na_2O	4·32		
SO_3	35·91	·446	4·00
H_2O	13·03	·724	6·49
CaO	0·35		
SiO_2	2·82		
MgO	*tr.*		
	99·37		

Tests showed that the silica came chiefly from included quartz grains. The remaining constituents, aside from the small amount of lime, are those of alunite, and by the usual calculation it is seen that they are present in the required ratio for that mineral, with a slight excess of water and of alumina, which can be referred, with a portion of the silica, to admixed kaolin, an observed associate of the crystals.

The unexpected result of the analysis was followed by a microscopical examination of thin sections prepared parallel to the basal plane of several crystals, and normal to that plane in a crystal with a glassy kernel. The fresh core possesses a cleavage parallel to the basal plane of the crystal, and its optical properties seem to be throughout those of alunite. The outline of the kernel is irregular. About the fresh alunite kernel is an aggregate of irregular particles, arranged without reference either to the outer crystal form or to the inner core. Those grains which are decidedly elongated polarize brightly, have sharp lines of cleavage parallel to the length, and the direction of major elasticity is always parallel to the cleavage lines. Many sections are not so elongated, and these polarize less brightly, some giving only gray tones, while a few are almost isotropic. The latter show a positive interference cross in convergent polarized light.

The facts which have been given seem to prove that the crystals in question are pseudomorphs of alunite after itself. An explanation of this anomaly is suggested by the volcanic history of the district. The crystals are almost certainly the result of solfataric action connected with the occurrences already described. If we suppose those alunite crystals to have been replaced by some other mineral, in which the bases were retained, a renewal of solfataric activity would naturally convert them into alunite again, but the protected cores of the original mineral could not influence the orientation of the new generation.

V. *Origin of the rocks described.*

In all of its observed occurrences alunite is a secondary product due to the action of sulphurous or similar acids upon highly aluminous rocks, yet there are two very different sites, with different attendant conditions, in which this action takes place. In the one case, the rock belongs to a clay bank and the acid is derived as a rule from the decomposition of marcasite in or adjacent to the clay. The product is a dark dense amorphous mass. In the other case, the agent is the sulphurous exhalation of a solfatara, and the rock acted upon is usually volcanic and rich in alumina and alkali—such a rock as rhyolite or trachyte. The product of this action is commonly a hard, rough, porous, highly crystalline rock, though a dense amorphous mass is often locally developed.

The alunite rock which has been described is directly comparable with the classic solfataric occurrences of Bereghszasz in Hungary, the island of Milo, and La Tolfa, near Rome. The writer has been unable to find mention of any similar occurrence on the American continent, and, judging from the descriptions given by von Richthofen* and vom Rath† of other localities, the rock of Democrat hill is remarkable for its purity, homogeneity and extent. Exactly similar material is not described by the authors named.

The limits of this article forbid any further comparison of occurrences or discussion of the processes involved in the formation of alunite, which are reserved for the monographic report upon the geology of the district.

While the alunite may be assumed to have been formed by the same processes which are involved in other cases, the diaspore of Mt. Robinson has apparently originated under conditions very different from those of any other known occurrence.

* In "Studien aus den ungarisch-siebenbürgischen Trachytgebirgen" Jahrbuch d. k. k. geol. Reichsanstalt, xi, 254–268, Vienna, 1860.

† Mineralogisch-geognostische Fragmente aus Italien. IV. Das Bergland von Tolfa. Zeitschrift der deutschen geol. Ges., xviii, 585, Berlin, 1866.

Its genesis, when in the ordinary association with corundum, emery, margarite, and other minerals, can have little in common with the present case. It has never been reported as an associate of alunite, nor as a decomposition product of eruptive rocks. The only previously observed occurrence connecting diaspore in any way with eruptive materials was recently mentioned by A. Lacroix,* who identified it as a minor constituent of a single block of gneiss, enclosed in a basaltic tufa of the Auvergne. This block is composed mainly of garnet, quartz, orthoclase and oligoclase, with rutile and diaspore, and is considered by Lacroix as an ejected fragment of a much metamorphosed rock, like many others in association with it. He does not refer to the novelty of this occurrence for diaspore, nor discuss its origin.

There is but little evidence upon which to formulate a theory as to the origin of the diaspore of Mt. Robinson, but after study of the specimens, it seems to the writer probable that it is here a result of the destruction of alunite At La Tolfa, alum is obtained by the slow roasting of the alunite rock, after which water extracts the soluble sulphate, but there is a residue of insoluble hydrate of alumina. Should this roasting and leaching take place in nature, it seems quite likely that subsequent conditions might lead to the crystallization of the residue as diaspore, making a porous quartz-diaspore rock. Some further agency would seem to be required to explain the occurrence of diaspore crystals in the cavities.

Art. LVI.—*Diaspore Crystals;* by W. H. Melville.

The crystals of diaspore, which Mr. Cross submitted to me for examination, present two types of combinations of planes referable to the prismatic or orthorhombic system of axes. One type consists of light brown transparent crystals which are elongated in that direction commonly chosen as the vertical axis, and which exhibit a largely developed brachypinacoid plane invariably much striated. This latter characteristic is true though to a less extent for the narrow prismatic planes. The crystals are doubly terminated, and are implanted in the associated rock upon one set of prismatic edges. A drawing of these crystals would resemble that given in Dana's Mineralogy, fifth edition, page 168, fig. 173. The following forms were observed.†

* "Sur l'existence d'une roche à diaspore dans la Haute-Loire." Bul. Soc. fran. de Min., xiii, p. 7, Jan., 1890.

† The symbols given are those of Miller and of Naumann as modified by Dana.

Brachypinacoid.		Brachydome.
[100], i-$\breve{i}$	[120], i-$\bar{2}$	[101], 1-$\breve{i}$
Prisms	[340], i-$\frac{4}{3}$	Pyramids
		[111], 1
[110], I	[670], i-$\frac{7}{6}$	[122], 1-$\bar{2}$

In the zone circle [111, 122] the mean of the most accurate measurements are given* under I, and another series under II. In almost all cases the signals reflected from the brachypinacoid were duplicated, so that it was often necessary to calculate the angle which this plane made with its adjacent planes from the difference of the sum of the other angles in the zone and 180°.

	Measured. I.	II.	*Kokscharof.
100 ∧ 111	63° 7	63° 20½	63° 5½
111 ∧ 122	12° 41½	12° 44	12° 40
122 ∧ $\bar{1}$22	28° 23	28° 23	28° 29
$\bar{1}$22 ∧ $\bar{1}$11	12° 41½	12° 39	12° 40
$\bar{1}$11 ∧ $\bar{1}$00	63° 7	63° 21½	68° 5½
	180°	180° 28′	

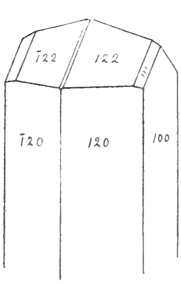
In the zone [100, 101] the measured angles were 100 ∧ 101 = 58° 50′ (1) and 58° 54′ (2); mean 58° 52′. For this angle Dana gives 58° 52½′ and Marignac 58° 53′. The following are the mean of the most reliable angles obtained in the zone of prisms:

100 ∧ 110	46° 54½	110 ∧ 670	4° 22	670 ∧ 340	3° 7½
340 ∧ 120	10° 20½	120 ∧ $\bar{1}$20	50° 31		

The axial ratio was calculated from the angles 100 ∧ 110 = 46° 54½ and 100 ∧ 101 = 58° 52.

$$\breve{a} : \bar{b} : \dot{c} = 0{\cdot}6457 : 1 : 1{\cdot}0689 \text{ found.}$$
$$= 0{\cdot}64425 : 1 : 1{\cdot}067 \text{ Dana.}$$

The second type consists of crystals which are white and almost opaque. They are stout and often present a pyramidal habit, as they are imbedded in the rock, resulting from the combination of the prism (120) and the octahedron (122). The annexed figure illustrates this habit of diaspore, and is drawn from a crystal which was removed from the rock and measured. The dominant forms are (120) and (122), while a macrodome (011), the brachypinacoid (100), and the octahedron (111) appear as small secondary planes. The crystals rarely show more than can be seen in the drawing, because they have grown into each other forming dense aggregates. The following angles were obtained from this crystal:



* The angles between normals are given in all cases.

	Between normals.			Between normals.	
$100 \wedge 111$	64° 5	approximate.	$122 \wedge 120$	54° 26	excellent.
$111 \wedge 122$	12° 3	"	$\bar{1}22 \wedge \bar{1}20$	54° 17	"
$122 \wedge \bar{1}22$	28° 20	excellent.	$120 \wedge \bar{1}20$	50° 7	

It is apparent from the foregoing tables that the crystals under discussion do not differ essentially in crystalline habit from those of the same species previously described by other mineralogists. The slight differences in the recorded measurements must be due to the imperfection of the surfaces from which the light is reflected. Reflected images of the slit of the goniometer have been frequently observed superimposed upon each other, and differing in position by two and three minutes. Errors arising from this source have been eliminated to a great extent in my tables of measurements by the choice of the mean value of many observations.

Chemical Laboratory of the U. S. Geological Survey,
Washington, D. C., Feb. 24th, 1891.

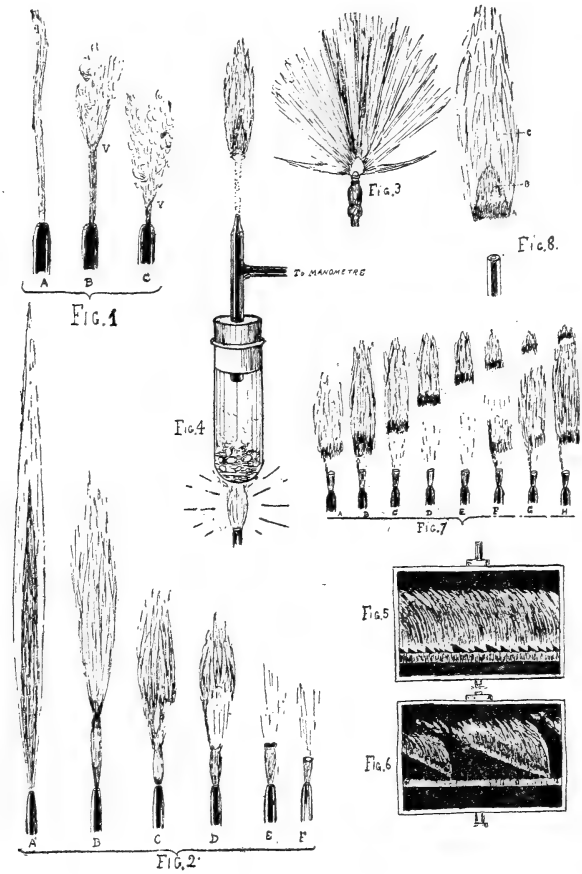
Art. LVII.—*Combustion of Gas Jets under Pressure;* by R. W. Wood, Jr.

Any one who has watched a burning jet of ether vapor has probably noticed that, as the pressure increases, the flame gradually retreats from the orifice, hovering in mid-air, as it were, and eventually goes out, if the pressure be carried beyond a certain point. In endeavoring to discover the exact cause of this, a number of rather curious phenomena were observed. Different gases were experimented upon, and found to act in very different ways, dependent apparently upon the relative amounts of oxygen required for their combustion.

The first experiments were made with coal gas, with pressures varying from 0·5 to 25^{cms} of mercury. The gas was drawn from a large reservoir, used for supplying an oxy-hydrogen lantern, at a tension of about ten pounds to the inch, the pressure at the jet being regulated by a stop-cock and measured by an open U-form mercurial manometer. With an orifice 1^{mm} in diameter, the following were the results obtained under varying pressures.

Pressure $0{\cdot}5^{cms}$—A quiet cylindrical flame, like a candle, 17^{cms} high (fig. 2 A). *Pressure* 1^{cm}—Flame 26^{cms} high. *Pressure* $1{\cdot}4^{cm}$—Flame 33^{cms} high, still quiet and tapering to a fine point; this pressure gave the maximum illuminating power to the flame. On increasing the pressure, the flame suddenly shortened, diminished in luminosity, and vibrated considerably, emitting a slight roaring sound which increased with the pres-

sure. *Pressure* 2^{cms}—Flame reduced to a height of 20^{cms}; hissed perceptibly. *Pressure* 3^{cms}—Its length about 17^{cms}; it roared loudly, and a contracted place appeared 4^{cms} from the orifice, fig. 2 B). *Pressure* 5^{cms}—Flame reduced to 15^{cms}, the contraction approached within $1{\cdot}7^{cms}$ of the orifice. Color, blue for the most part, a little yellow at the tip, very little luminosity.



Pressure 7^{cms}—Yellow tip all gone; small broken spaces appeared in the flame beyond the contraction; resembled the flame of a Bunsen blast lamp and was about as hot; glass could be worked in it as easily as in the blowpipe flame (fig. 2 C). *Pressure* 10^{cms}—A large break appeared in the flame just beyond the contraction; the flame beyond united with that below by a mere thread (fig. 2 D). *Pressure* 11^{cms}—Flame beyond the break alternately went out and relighted with a snapping noise, showing that it was an explosive mixture of gas and air.

Pressure 12^{cms}—Flame beyond the contraction went out, and there was left only a short tube of blue fire, as sharply defined as if made of rigid matter (fig. 2 E). Through this tube a vast quantity of unconsumed gas flowed, which was so cold that the eye could be brought directly over the tube, when it was seen to be distinctly hollow, with thin sharply defined walls. *Pressure* 20^{cms}—Tube shortened to one-half its former length, and the walls became thinner (fig. 2 F). *Pressure* 23^{cms}—The tube went out.

The formation of the tube is a rather curious phenomenon. It appears to be due to the fact that the gas molecules on the outside are moving slower than those within, the speed being reduced by friction with the walls of the orifice. What we have then is a jet of gas moving at high speed surrounded, below the contracted place (where the air mixes with it), by a shell of gas moving at a velocity so low that it will remain ignited; with an increase of pressure we should expect the shell to become thinner, and this is exactly what happens. Burning the gas in oxygen, the jet will stand a far greater pressure without forming a tube or blowing itself out. In fact it is difficult to raise the pressure high enough to bring this about. Were we dealing with a flame of pure hydrogen, burning in an atmosphere of oxygen, it would be impossible. Any one who has used the oxy-hydrogen blowpipe knows that it is impossible to give a velocity to the mixed gases great enough to extinguish the jet. The rate at which flame will run down such a jet, or rather the rate at which combustion takes place through a mixture of two parts of hydrogen and one of oxygen is 2500 meters (more than a mile and a half) a second. That is to say, if we had a tube a mile and a half long filled with the mixture, the flame would traverse it in one second. The explosion would be practically instantaneous. Contrast this with coal gas and air. Fill a glass tube a meter long and an inch in diameter with a mixture consisting of 1 part of coal gas to 10 of air. Apply a flame to the open end, and a disc of blue fire will descend the tube with a whistling noise at the rate of about 18 inches a second! The reason why the jet of coal gas blows itself out is very obvious; its velocity is greater than 18 inches per second, consequently it carries the flame away, so to speak. To cause an oxy-hydrogen jet to act in a similar manner we should have to give it a velocity greater than 2500 meters a second. To determine the exact form of the jet when not ignited, the gas was passed through two bulbs, each filled with asbestus, that in one bulb soaked with ammonia, in the other with hydrochloric acid. The gas, passing through these bulbs, became charged with dense white fumes of ammonic chloride, which rendered the jet plainly

visible. At a very low pressure, too small to be accurately measured by the manometer (say about $0{\cdot}1^{cm}$), the column of gas rose unbroken like the smoke of an extinguished candle (fig. 1 A), and a burning match applied to the top of the column would ignite the jet, the flame running down to the orifice and burning quietly there. On blowing out the flame and increasing the pressure a little, the column broke into a fan at a definite height (V, fig. 1 B). Below this point, the regular outline was preserved, but above it the gas diverged rapidly in whirling masses. To ignite the jet permanently, it was now necessary to apply flame below the point V. If applied above, the gas beyond the match burnt with a roaring blue flame, which went out the instant the match was withdrawn, or if the velocity was not too great, hung for a few moments in mid-air. The point V, where the divergence commences, is evidently the point where air is being mixed with the gas. Increasing the pressure brings the point nearer and nearer the orifice, until finally there is scarcely a trace of the unbroken column.

Let us now consider why it is necessary to bring the flame below V in order to ignite the jet permanently. Above this point there is a mixture of gas and air, which is moving at a rate considerably greater than 18 inches per second, consequently the flame is carried up by the jet faster than it can run down. Below the point V we have a stream of undiluted gas, down which the flame will travel rapidly enough to keep the jet permanently lighted, for then the gas above V will be kept lighted by the flame below. What we should expect would be a quiet cylindrical yellow flame below V, and a roaring, flaring, blue flame above, but this is not what happens. On bringing the match below the point of divergence, the burning mass above ceases to flare, and the whole subsides into a quiet tapering yellow flame. The pressure may be increased some centimeters before the tip begins to flare and burn with a blue flame. The reason for this is not very obvious. Igniting the jet appears to bind it together and prevent entrance of air.

With an ordinary four-foot bat-wing burner the best flame was given by a pressure of about $1{\cdot}3^{cms}$ of mercury. A pressure of 2^{cms} gave a quiet flame, but there were lateral horns at the bottom. At 6^{cms} the luminosity was greatly diminished, wide horns formed, and radiating streaks appeared in the blue part. At 12^{cms} the luminosity was nearly gone, and a dark arch of unconsumed gas appeared above the orifice, fig. 3. A pressure of 20^{cms} widened this arch, and rendered the flame non-luminous. At 25^{cms} the flame blew itself out.

These experiments were repeated with ether vapor, the pressure being derived by boiling the fluid. Owing to the

rapid condensation, considerable difficulty was experienced in keeping the pressure uniform during the observations. The tubes leading from the flask to the manometer had to be kept hot in order to prevent fluid ether instead of vapor from being delivered at the orifice, which in this case was smaller, being about the size of a small sewing needle.

With coal gas this jet would stand a pressure of 20^{cms} without going out. With ether vapor $\frac{1}{5}$ of a centimeter gave a flame like a candle, while $\frac{1}{2}^{cm}$ caused the flame to retreat about a centimeter from the orifice and burn in mid-air. At $\frac{7}{10}^{cm}$ pressure the distance had widened to four centimeters, and the vaporized ether could be seen rising as a cylinder the size of a knitting needle surmounted by a hollow blue flame, fig. 4. At 1^{cm} pressure the flame went out! It behaved very much as coal gas did when burnt in bad air, the flame showing no tendency to form a tube under increased pressure. This seems to be due to the fact that ether vapor requires a greater amount of oxygen for its combustion. In pure oxygen it behaves very much as coal gas does in air. Alcohol vapor comes between the two, the flame standing a pressure of about 3^{cms} without being extinguished, and showing a tendency to form a tube.

The nature of these flames was studied with a revolving mirror, but no interesting features were revealed except in the case of the coal gas under high pressure. The action of the rotating mirror is to spread out the flame in a broad band, giving as it were an infinite number of instantaneous views, placed side by side. If the upper parts of the jet move slower than the lower, they will suffer lateral displacement, and the flame images will be curved backwards. The flame shown in fig. 2 C when examined in the mirror appeared as in fig. 5. The serrated part of the flame represents the contracted portion, and the alternate dark and light spaces show that this part of the flame alternately ignites and goes out, with sufficient speed, however, to keep the gas above in a state of continuous combustion. The long narrow band below is the burning tube of gas, and the bright teeth are rapid flashes of fire uniting this with the burning mass above. Under greater pressure the frequency of these flashes becomes reduced to such a degree that they are appreciable to the eye. This is the case in flame D (fig. 1). Here the upper portion alternately ignites and goes out with a rapid snapping noise, the pulses varying from one to ten a second. In the rotating mirror this flame presents the appearance shown in fig. 6, the flashes being so slow that they are completely isolated from each other by the mirror, each one being seen as a broad flare of light. The line representing the tube of fire is narrower now, the pressure being greater. The slanting base of the "flare" is bright blue, above this is a

faint green tinge, while still higher we find the light purple tint of the Bunsen flame. The appearance of this flame in the mirror clearly indicates what is taking place. The mass of gas above the contracted place, after being ignited by a flash from the continuously burning tube, does not immediately go out. The flame fights its way down the ascending column, but continually loses ground, owing to the great velocity of the jet. The second flash comes often before the tip of the first one has gone out, and if the interval is short enough the flashes will mingle. In fig. 7, I have attempted to show this in a clearer manner. The series shows an interval of one flash, the figures representing instantaneous views of the flame at successive moments of time. Figs. A to E show the gradual dying out of the flame of the first flash. At F the second flash has commenced, and at H it has risen and mingled with the last vestige of the first.

By carefully regulating the pressure, we may give to the jet a velocity which shall equal the speed of combustion for the mixture of gas and air. The flame will now hang balanced in the air, as shown in fig. 8, the tendency of the fire to spread downward being exactly neutralized by the upward motion of the column. On examining this flame the cause of the bright blue and faint green lines in the mirror is discerned. Around the base of the flame the mixture burns with an intense blue light (fig. 8 A); surmounting this is a cone of greenish fire B, while above this the flame has a light purple tinge.

ART. LVIII.—*Allotropic Silver. Part III. Blue Silver, soluble and insoluble Forms;* by M. CAREY LEA.

WHEN my first paper on the subject of allotropic silver was published about two years ago, that substance seemed to be the result of a very limited number of reactions closely allied to each other. Further study has shown that it is a much more common product than at first appeared to be the case. Wherever in the reduction of silver a reddish color shows itself, that may be taken as a probable indication that allotropic silver has been formed, even although it may be destroyed before it can be isolated.

What is rather remarkable is that allotropic silver is produced abundantly in certain very familiar reactions in which its presence has never been suspected: so abundantly in fact that some of these reactions constitute the best methods of obtaining silver in the soluble form. In photographic operations silver has often been reduced by tannin in the presence

of alkalies. It has not been imagined that by slightly varying the conditions, the whole of the silver may be made to pass into solution as a soluble metal with its characteristic intense blood red color.

Some of these new reactions will be here described in detail.

Allotropic Silver obtained with Dextrine and Alkaline Hydroxide.

When dextrine is dissolved in a solution of potassium or sodium hydroxide and silver nitrate is added, keeping the hydroxide in moderate excess, the silver is at first thrown down in the form of the well known brown oxide. This brown color presently changes to a reddish chocolate shade and at the same time the silver begins to dissolve. In a few minutes the whole has dissolved to a deep red color, so intense as to be almost black. A few drops poured into water give it a splendid red color of perfect transparency. Examination with the spectroscope leaves no doubt that we have to do with a true solution.

It is interesting to observe that silver can be held in solution in neutral, acid and alkaline liquids. In the first process which I published, in which silver citrate is reduced by a mixture of sodic citrate and ferrous sulphate, the latter may be used either in acid solution or it may be first neutralized with alkaline hydroxide, so that that form of silver is held in solution in either a neutral or an acid liquid. The form that is obtained with the aid of dextrine dissolves most freely in the strongly alkaline liquid in which it is produced, and when dilute nitric or sulphuric acid is added the silver is precipitated. But with acetic acid the precipitation is very incomplete: the solution retains a brown color and contains silver. Even the addition of a large excess of strong acetic acid fails to throw down any more silver. It follows therefore that while this form of silver is most freely soluble in a strongly alkaline liquid it is also soluble to some extent in one that is either neutral or acid.

The precipitate when once formed appears to be almost insoluble. A small portion of it stirred up with distilled water gives no indication of solution. But if a quantity is thrown on a filter and washed, as soon as the mother water is washed out the liquid runs though of a muddy red, and if this filtrate be allowed to stand it deposits an insoluble portion and then has a fine rose-red color and perfect transparency. Notwithstanding the beautiful color it contains a trace of silver only, so great is the coloring power of the metal. Sometimes if the alkaline solution stands for a month or two the silver becomes spontaneously insoluble; most of it falls to the bottom as a deep red substance, but part remains in suspension

with a bright brick red color. The difference between this and the true solution as originally formed is extremely well marked.

Dextrine is a very variable substance and different specimens act very differently. Common brown dextrine seems to do better than the purified forms.

Convenient proportions are as follows: in two liters of water forty grams of sodium hydroxide may be dissolved and an equal quantity of dextrine, filtering if necessary. Twenty-eight grams of silver nitrate are to be dissolved in a small quantity of water and added by degrees at intervals. Complete solution readily takes place. Although the liquid contains less than one per cent of metallic silver it appears absolutely black, when diluted, red, by great dilution yellowish. With some specimens of dextrine the solution remains clear, with others it soon becomes a little turbid.

Perhaps the most interesting reaction which this solution shows, is that with disodic phosphate. A little phosphate is sufficient to throw down the whole of the silver although both solutions are alkaline. When a gram of phosphate in solution is added to 100 c.c. of silver solution the color becomes bright red, sometimes scarlet, and the whole of the silver is presently precipitated. This precipitate on the filter has a color like that of ruby copper, which color it retains during the first washing, but after a few hours' washing with distilled water the color changes to a deep Nile green and at the same time it becomes slightly soluble, giving a port wine colored solution. With more washing this solubility may disappear.

It is a general fact that all these forms of silver, however various their color, have both a body and a surface color and these two colors tend always to be complementary. The body color is that shown by the precipitate while still moist; it is also visible when a thin coat is brushed over paper, a coat so thin that light passes through it, is reflected by the paper and returned again through the film. But when a thick and opaque film is applied, the body color disappears and only the complementary surface color is visible.

So in the case of the precipitate by phosphate, when the substance resembling ruby copper is spread thickly on paper it dries with a bright green metallic surface color. But when the substance itself becomes green by continued washing it assumes on drying a dark gold or copper color, the surface color changing with the body color and maintaining its complementary relation. In observing these effects one is constantly reminded of certain coal tar colors, both by the great intensity of coloration and by the metallic surface color. I am

not aware that any other inorganic substance shows this resemblance to a similar extent.

These forms of allotropic silver have a great tendency to attach to themselves foreign matters. Although the dry substance has all the appearance of a pure metal it may contain as much as 8 or 10 per cent of organic matter which it is utterly impossible to detach. I have taken much trouble to eliminate this substance. In one attempt hot distilled water was forced through with the aid of a filter pump for over 100 hours without effect. The presence of this organic substance becomes evident when the metal is heated in a tube. A vapor arises which condenses into small brownish drops having an empyreumatic odor. The residue of bright white metallic silver, when dissolved in nitric acid, leaves behind black flakes of carbon. When the allotropic silver is dissolved in dilute nitric acid and the silver precipitated by hydrochloric acid, on evaporation a small residue of a yellowish gummy substance is obtained.

Analyses.—Four silver determinations were made of material rendered as pure as it was found possible to obtain it. Results—

No. 1	93·77	p. c. Ag.
No. 2	94·27	" "
No. 3	92·86	" "
No. 4	96·64	" "

Allotropic Silver obtained with Tannin and alkaline Carbonates.

Tannin (gallotannic acid) in alkaline solution reduces silver nitrate to metallic silver in the allotropic form. Tannin acts more strongly than dextrine and therefore does best with carbonated alkali, dextrine best with alkaline hydroxide, although either substance will produce the reaction with either form of alkali and, though less advantageously, with ammonia. Tannin with sodium carbonate gives a very perfect solution of silver, quite free from the turbidity that is apt to characterize the dextrine solution. The color of this solution is likewise very intense: one containing one per cent of silver is quite black, by dilution deep yellowish red. It has very much the same characters as the preceding, but is rather more stable. To obtain it, 24 grams of dry sodium carbonate may be dissolved in 1200 cc. of water. A 4 per cent solution of tannin is to be made and filtered, of this 72 cc. are to be added to the solution just named: of silver nitrate, 24 grams dissolved in a little water are to be added by degrees. Solution takes place almost instantly as each successive portion is added. The solution after standing a day or two may be decanted or filtered from a small quantity of black precipitate.

When the solution is treated with a very dilute acid, as for example, nitric acid diluted with twenty times its bulk of water, allotropic silver is precipitated in the solid form. It dries with a brilliant metallic surface color of a shade different from the foregoing and somewhat difficult to exactly characterize, a sort of bluish steel-gray.

I do not find that blue allotropic silver (in which is included the green and steel-gray varieties) can be reduced to any one definite type. On the contrary, its variations are endless. Slight differences in the conditions under which the solutions are formed or in the mode of precipitation give quite different products. For example, of ten products obtained with tannin and sodium carbonate in different proportions, several were easily and completely soluble in ammonia, some were slightly soluble and some not at all. Some specimens not at all soluble in water became so by moistening with dilute phosphoric acid: they did not dissolve in the acid but when it was removed they had become soluble in water. On other specimens phosphoric acid had no such effect. Some solutions are scarcely affected by acetic acid, others are partly precipitated, others almost but not quite wholly. The films spread on paper vary very much in their relations to light; some are readily converted into the yellow intermediate form, whilst others are very insensitive. The least sensitive specimens seemed to be those for which dilute nitric acid had been used as a precipitant. They had a steel-gray color. Precipitation by acetic acid seems to tend to a greenish metallic surface color and greater sensitiveness. Different specimens also vary very much as to permanency; this character is also affected by the amount of washing received: thorough washing tends to permanency.

In some way the blue, gray and green forms seem more closely related to the black or dark gray forms of normal silver, for they tend in time to pass into them, while on the contrary, gold-colored silver, if pure, tends with time to change to bright white normal silver on the surface, with dark or even black silver underneath.

Action of other Carbonates.

Tannin is capable of producing allotropic silver, not only in the presence of the carbonates of potassium and sodium, but also with those of lithium and ammonium and also with the carbonates of calcium, magnesium, barium and strontium. The action of the last named carbonate has been more particularly examined. It yields allotropic silver of a dark red color while moist, drying with a rich bluish green metallic surface color in thick films, in very thin films transparent red. It is probable

that the substances with which tannin produces these reactions would be further increased by investigation.

I have found some additional modes of production of these forms of silver, modes which are very curious and interesting. They are now being studied and will be reported on hereafter.

Nature of the "intermediate substance."

It has been mentioned in previous papers that when allotropic silver is converted into normal silver by the action of heat it passes through a perfectly well marked intermediate state. In this state it retains the gold-yellow color and high luster but none of the other properties of the original form. Oxidizing and chlorizing agents show nearly the same indifference as with ordinary silver. While allotropic silver is soft and easily reduced to powder the intermediate substance is hard and tough. When a glass rod is drawn over a film of allotropic silver it leaves behind it a white trace of ordinary silver. The intermediate substance shows no such reaction: the trace of a glass rod does not differ from the rest of the film and even hard burnishing produces no change in the color. Continued exposure to sunlight brings about the same alteration to the intermediate form and it takes place spontaneously with time.

At that time no explanation could be found as to the nature of the change. It proves however to be a passage into a crystalline form. Some films spread on paper were exposed to the action of very dilute solution of ferric chloride. It chanced that one of these films had undergone a partial change into the intermediate form; the unchanged portion was darkened by the ferric solution, while the portion that had passed into the intermediate form retained its bright gold-yellow color and luster, rendering it thus distinguishable. The figures which it exhibited were strikingly crystalline. One portion showed a foliated structure such as is formed by interpenetrating crystals, other parts showed ramifications with something of a plant-like form. Another part exhibited a sheaf of acicular crystals nearly parallel in direction, half an inch to an inch long and as fine as hairs. These appearances indicated with certainty crystalline structure. Other specimens have been obtained though none so well defined as that just mentioned which happened to be taken at exactly the right stage of spontaneous alteration to make the structure manifest. The alteration is not apparent to the eye as the color does not change.

This change to the crystalline condition does not seem to be peculiar to gold-colored silver. The blue form when gently heated in a tube becomes yellow. By continued heat it changes to white normal silver. A film on glass began to

change from blue to yellow at about 180° C. Light also produces this change on blue silver. The specimens obtained by different processes act very differently; some change with a few hours of strong sunlight, others require many days.

From what has been written in this and preceding papers it appears that allotropic and even soluble silver may be formed in a great variety of reactions. The reducing agents may be either a ferrous or a stannous salt or any one of a variety of organic substances of very different constitutions. From the solubility and activity of this substance and the parallelism which many of its reactions show to those of silver in combination, I have been disposed to think that silver in solution might, like silver in combination, exist in the atomic form. It is certain that up to the present time we have no positive knowledge of the existence of any element in the atomic form as a solid. We know that four or five metals are atomic in their vapors and that in iodine vapor at a certain temperature the molecules separate to atoms.

But it may be questioned whether we have not seen solid elements in the atomic form without recognizing them as such. There are forms of iron, nickel, cobalt and lead which exhibit very remarkable properties, properties that have been hitherto very unsatisfactorily explained. Lead tartrate reduced by gentle ignition in a nearly closed tube and allowed to cool and then shaken out into the air forms a stream of fire. The oxides of iron, nickel and cobalt reduced in closed tubes by hydrogen show similar properties. It is customary to explain this action by affirming that the metals are left in an extremely fine state of division. This explanation is not satisfactory. Sulphur, for example, is far more inflammable than any of the metals just mentioned and may be obtained in a state of exceedingly fine division, either by sublimation or by precipitation, but does not in consequence show any greater tendency to spontaneous inflammation. It seems more natural to suppose that these metals are reduced in the atomic form, and this view of the matter seems to be much strengthened by the following considerations.

The experiments of Ramsey, and of Heycock and Neville, cited in a previous paper, lead to the conclusion that in the case of a dilute solution of one metal in another the dissolved metal exists in the atomic form. But still more the experiments of Tammann on amalgams indicate that in these alloys the dissolved metal is atomic, and it is stated that Joule by distilling off the mercury from an iron amalgam found that the iron was left in a pyrophoric condition. The amalgam of manganese, carefully distilled, gives a pyrophoric powder. Chro-

mium amalgam, distilled in a current of hydrogen, gives a similar result if the temperature is not raised too high. The enormous affinity which these forms of metals exhibit for oxygen renders their study very difficult. It has not been before suggested that their activity is due to their being atomic, but this would seem to be a much more rational explanation than that of extreme division.* A broad distinction must of course be drawn between chemical and mechanical division: a substance may be atomic and yet appear in masses: may be in the finest mechanical division and yet be molecular or polymerized. Silver being a metal with a very low affinity for oxygen could not be expected to show in the atomic state the same inflammability as more oxidable metals.

In conclusion it may be said that there is much reason to suppose that elements may exist in the atomic form and that allotropic silver may present such a case. This is of course far from being proved and is offered only as a "working hypothesis." As such it may afford a useful aid in further investigations.

Philadelphia, April, 1891.

ART. LIX.—*Notes on the sub-marine channel of the Hudson River and other evidences of Post-glacial Subsidence of the Middle Atlantic Coast Region;* by A. LINDENKOHL. With Plate XVIII.

THE American Journal of Science of 1885† contained an article by the writer entitled "Geology of the Sea Bottom in the Approaches to New York Bay," in which a description was given of a remarkable depression in the sea bottom off Sandy Hook and an attempt was also made to account for the origin of this depression and to trace its connection with the geology of the adjacent coast region.

Professor Dana, who was the first to recognize the true shape of this depression and to direct attention to its existence by a map and reference in his "Manual of Geology," published in 1863, takes up the subject again in a recent number of this Journal,‡ treating of Long Island in the Quaternary with observations on the sub-marine Hudson River channel, and carefully

* M. G. Rousseau, in the new Encyclopédie Chimique, seems to entirely abandon the old view of extreme division and considers these forms to be allotropic and comparable with the allotropic forms of phosphorus, etc. Vol. iii, page 56.

† Vol xxix, pp. 475 et seq., also republished as Appendix No. 13, U. S. Coast and Geodetic Survey, Report of 1884.

‡ Vol. xl, pp. 425–437.

reviews the well-ascertained facts connected with this depression but on several points reaches quite different conclusions.

It is the object of the following pages to review the subject, and at the same time to introduce much information bearing upon it, which has accumulated since 1885, but has not appeared in print.

Description of the Sub-marine Hudson River Channel.—The sub-marine depression, to which reference is made in the preceding paragraphs, has the characteristics of a river channel unmistakably impressed upon it and it is recognized as the submarine continuation of the Hudson River channel. It is first noticed at a depth of twenty fathoms, about twelve statute miles southeast from Sandy Hook. Its course is nearly south until abreast of and eleven miles from Long Branch, where it has attained a depth of thirty fathoms in fifteen fathoms of water. Thence it begins to turn to the southeast and attains its greatest depth of forty-five fathoms when fifty-three miles from Sandy Hook, the banks rising on both sides of the channel to a height of fifteen fathoms within two or three miles. From here its depth begins to fall off until, at a distance of ninety-one miles from the Hook, the channel almost disappears with a depth of but forty-one fathoms in a surrounding bottom of thirty-nine fathoms depth. But, at a distance of ninety-seven miles, the channel begins to assume the character of a gorge or cañon, which character it maintains for a length of twenty-three miles, when it vanishes on the edge of the great continental plateau at a depth of about 200 fathoms. The average width of the river channel is about $1\frac{1}{4}$ miles, that of the gorge three miles with a greatest depth of 474 fathoms in about seventy fathoms of water.

The bottom of the river channel and cañon as well as their slopes consist of a bluish slate-colored mud or clay with a fine sandy grit. This mud bottom extends for a considerable distance on both sides, north and south of the cañon along the brink of the continental plateau.

In trying to account for the existence of the upper part, or river portion, of the channel, it was assumed to be the result of fluvial erosion and to imply a subsidence of about 210 feet at a comparatively recent geological time, subsequent to the glacial period. The existence of the gorge was believed to imply a much greater subsidence than that of the upper channel, a subsidence not far from 1200 feet (200 fathoms). No attempt was made to fix its geological date beyond the statement that its fiord-like shape favors the supposition that it existed as an elevated channel during a part at least of the glacial era, but that it must have sunken below the level of the

ocean at the time when its feeder was yet an actual river channel.

The presence of clay on the bottom of the channels and on the slopes, and its absence elsewhere, was assumed to furnish proof for the assumption that this clay was not a mere superficial covering, but that it is formed *in situ* and gives indications of strata in correlation with the Tertiary exposed towards the northeast at Gay Head, as well as with that of New Jersey, bearing west.

The first one of these propositions, the one which accounts for the sunken river channel, is the most important and perhaps the most vulnerable one, and requires proof of the following corollaries:

1st. The shape and dimensions of the channel must accord with those which should be assigned to a hypothetical river of the size of the Hudson.

2d. Tidal and other currents now in existence cannot have produced the channel.

3d. A similar subsidence which must not necessarily be of the same amount, must be proved for the nearest rivers to the south, for the Delaware, Susquehanna (or Chesapeake) and Potomac. (The rivers to the north may be left untouched since Professor Dana has investigated the subject and recorded the results in his paper on Long Island Sound in the Quaternary, etc., mentioned above.)

4th. It must be shown that diluvial deposits do not lie conformably on the surface of these channels but are eroded by them, and all deposits found in the channels must be of alluvial character.

1. *Size and shape of the Sub-marine Hudson River Channel.*—The breadth of the channel is about one and a quarter miles, about the same as that of the river above the Narrows. From New York City to the Dunderberg the channel is about three-quarters of a mile wide. These dimensions tally well with the conditions expected from an ordinary tidal stream, i. e. increased capacity with nearer approach to sea. The main slope of the banks is 1°. This is less than we expect of living rivers, but we should take into consideration that, apart from currents, the corrasive action of sea water is constantly engaged upon the work of destruction. It is rather a matter of surprise to those who are familiar with the little power of resistance of clay banks in sub-aerial exposure when unprotected by gravel ledges or turf, that such banks should be preserved at all under the sea. No special reason can be assigned for the peculiarity that the river should first flow fifteen miles to the south before turning east unless we assume that it follows the fashion set by its neighboring rivers, the

Delaware, Susquehanna, and Potomac, which all follow a southern and anticlinal course before they take up the straight road to sea. This uniformity in behavior of these four rivers points to a common cause, and a slight tilting of the Atlantic plain in a north and south direction suggests itself as the readiest way to account for the southern deflection of the rivers.

Effects of existing currents on the sub-marine channel.—The following table, giving the mean maximum strength of both sets of tidal currents in nautical miles, has been compiled from the latest observations for the purpose of testing the ability of those currents to create channels outside of the Sandy Hook bars.

Table of Tidal Currents in the lower New York Bay.

	Mean Maximum Ebb.		Mean Maximum Flood.	
	Surface.	Bottom.	Surface.	Bottom.
Narrows	1·9	0·9	1·3	1·0
Fourteen Foot Channel	1·9	0·9	1·6	1·0
East Channel	2·2	0·9	1·6	0·8
Swash Channel	2·1	0·9	1·8	1·2
Main Ship Channel	2·3	0·8	1·8	1·2
Outer East Channel	2·1	1·2	1·6	0·9
Gedney's Channel	2·3	0·9	1·8	1·0
South Channel	2·2	0·2	1·4	0·7

It will be seen from this table that the ebb current is the strongest surface current and maintains its velocity (1·9 to 2·3 knots) until the outer bars have been passed. But its strength at the bottom of the channels is less than half that of the surface currents, and less than that of the flood current. The flood current is essentially a deep current and retains at the bottom, in spite of friction, nearly two-thirds of its surface velocity; it is the flood current's speciality to attend to the scouring business. But we cannot realize that a current which has but 1·2 nautical miles velocity at the places where it must be supposed to exert its greatest strength, can have the power to scoop out a channel forty-five feet deep and only a mile wide at a distance of fifty miles from the coast. At the same time the opinion is well-founded that the submarine channel is the principal passage way for the tide to and from New York Bay, and that this almost ceaseless flow tends to keep the channel clear from encroachments, especially by that formidable bank, the Cholera Bank on the New York side of the channel. Often the tides may be reinforced by high seas produced by continuous easterly winds off New York; and although such high tides are known to be very destructive along the whole coast from Atlantic City to Fire Island, we have no reason to believe their effect to extend to greater depths than fifteen fathoms or to the depth of our channel.

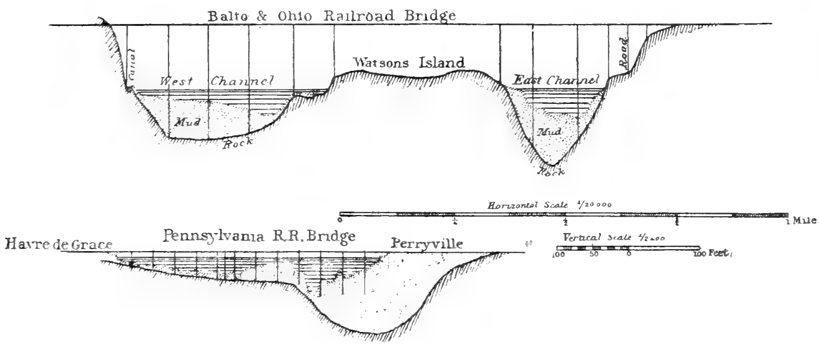
Sunken River Channel in Chesapeake Bay.—As stated above, if the theory of a recent subsidence of the Hudson River is to be successfully maintained, a similar subsidence must be proved for the Delaware and for Chesapeake Bay. It must be confessed that for many years we have been searching for sunken channels for those bays without finding them; we were looking for them in a wrong direction, outside of the bays, instead of inside. We supposed Cape Henlopen and Cape Henry occupied relative positions to those channels analogous to that of Sandy Hook to the sunken Hudson River channel; we took the Coast-line as our line of departure instead of taking the *Fall-line.* This line which is easily identified by the site of New York, Trenton, Philadelphia, Havre de Grace, Baltimore, Washington, etc., separates two widely different geological regions, the region of crystalline and Triassic rocks to the north and west from the stratified clays and gravels to the south and east, and it must be assumed that any seismic disturbance would affect these two regions unequally and the coastal plain to a greater extent than the Piedmont region.

Now, the *sinking* of the land to the extent of 100 feet, let us say fifty feet, would hardly affect the physiography of those parts of the country above the hypsometrical line of fifty feet, but all land below this level would be appropriated by the waters and reached by the tides; rivers with low shores would be converted into bays or estuaries, those situated in rising ground would have the lower parts of their valleys flooded. It now remains for us to examine Delaware and Chesapeake Bays for traces of deeper and narrower channels than those which can be accounted for by existing conditions.

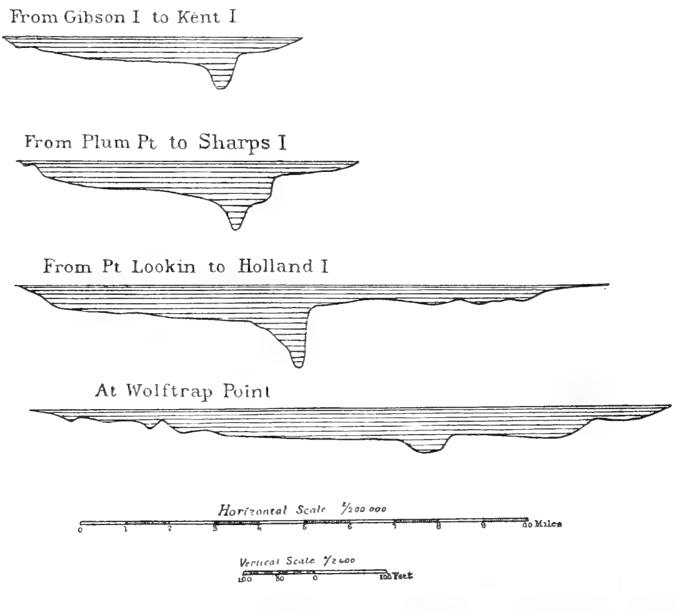
Passing Delaware Bay, for reasons which will be explained farther on, and turning to Chesapeake Bay, we readily find, upon examining the soundings, a narrow and deep inner channel which can be traced nearly through the entire length of the bay, from the mouth of Bush River to that of the Rappahannock, a distance of 120 miles. In an average width of the bay of ten miles, this channel commences with one mile's breadth in its upper part, increasing to two miles near its southern limit. The descent of the bottom of the bay is very gradual from the shore until the depth of eight fathoms is passed, when the bottom abruptly plunges to the depth of about twenty fathoms (from fifteen to twenty-six fathoms). The bathymetrical line of forty-eight feet may then be taken as the limit of this inner deep channel. We subjoin four cross-sections of the bay, taken about thirty-five miles apart. It will be seen that the areas of these sections are gradually increasing,

going down the bay and that the last one, that off Wolftrap Point below the Rappahannock, is the largest, although the

Cross Sections of the Susquehanna River



Cross Sections of Chesapeake Bay



deep cut in the bottom is missing. It does not matter what particular curve we accept as a type of cross-sections of tidal

streams, whether an ellipse or parabola, the cross-section at Wolftrap comes nearer to it than any of the preceding ones and no combination of circumstances, no shifting or turning of channel can satisfactorily explain, as a purely tidal phenomenon, the existence of the deep incisions at the bottom of the cross-sections. We are forced to conclude that these incisions are due to pre-existing conditions, that they show the former channel of a river at a time when the whole region lay about forty-eight feet higher than at present, when Chesapeake Bay did not exist, but when the Susquehanna was at least 150 miles longer than at present (rather more than the submerged Hudson) and gathered upon its way to the sea the waters of the Patuxent, Potomac and Rappahannock. The reason that we cannot trace the channel farther up the bay than Bush River and to the mouth of the Susquehanna is, no doubt, owing to the fact that the Susquehanna has filled up the upper part of its old channel, for which it has no further use, with its sediment; and the borings to a depth of 140 feet at Fishing Battery, below Havre de Grace, through alluvium, which Mr. McGee reports,* quite favor such a supposition. As stated above, the channel disappears below the mouth of the Rappahannock with a depth of about fifty feet. I am not prepared now to answer the question, whether the bar and actual end of the old river is here or whether there is but a temporary interruption of the channel by subsequent deposits from rivers emptying into the bay. The answer is not material to the present inquiry. The river channel appears to have hugged its eastern shore, which in several places appears to have risen into bluffs, from 15 to 25 feet high, while the western shore was low and marshy. The soundings in the bay are not the only indications of a depression; they can be found everywhere along the shores of the bay, even by a mere inspection of the charts. It is entirely beyond the ability of the present sluggish streams to have eroded their channels to the great width which is so characteristic of the lower part of all streams entering the Chesapeake. The absence of deltas and bars at the mouths of the rivers, the almost total absence of drainage-area for a long strip of the western shore of the bay above the Rappahannock, all are suggestive of subsidence, in fact have been commented upon in this direction by Mr. McGee in his exhaustive study of the Geology of Chesapeake Bay.† On more than one occasion he speaks of the drowned rivers of the bay.

There is another way in which we may arrive at an estimate of the probable amount of subsidence. The profile given (p. 494) of the Susquehanna River at the crossing of the Baltimore and

* Seventh Annual Report U. S. Geological Survey, p. 580.

† Seventh Annual Report, U. S. Geological Survey, pp. 537–646.

Ohio Railroad bridge above Havre de Grace, kindly furnished by Mr. Chas. F. Mayer, the President of the road, shows a considerable layer of mud intervening between the bottom of the river and the rocky granite floor. This layer has a thickness of fifty-nine feet in the west, and over seventy feet in the east channel. The river would most certainly not have cut a channel into one of the hardest of rocks if there had not existed, at some time, a physical necessity for it, and the amount of filling or "packing" of mud enables us to estimate the depth of the river at that time. Assuming the discharge to be stationary, we find that, supposing the mud to be removed, the river could be lowered forty-three feet and yet find sufficient space for the passage of its waters. The next profile (p. 494) is from the crossing of the Pennsylvania Railroad at Havre de Grace, about one mile to the southward of the B. & O. R. R. bridge. This profile was obtained from Mr. G. B. Roberts, President of the Penna. R. R. It shows the greatest depth of mud, 113 feet under the wharf at Perryville. It would appear then that the channel of the river ran very closely to its eastern shore which was then several hundred feet farther inland. The rock is stated by Mr. McGee to dip under the level of the river about one-quarter of a mile from the railroad bridge. A similar calculation for the level of the river with the rocky floor for its bed, instead of the muddy bottom, gives fifty feet below the present surface. These two estimates taken in connection with the result of borings at Fishing Battery mentioned above, would appear to prove that at the time when the level of the Chesapeake was forty-eight or fifty feet lower with respect to the land than at present, Perryville and not Port Deposit, was at the head of tide and that strong currents swept down the Susquehanna past and on both sides of Watson Island, plowing into the clays of the coastal plain to a depth of ninety feet or more.

The Potomac being a tributary of Chesapeake Bay, we should naturally expect indications of a sinking of the land at the head of tide, similar to those of the Susquehanna. An examination of several profiles of the river at the Free Bridge in Georgetown (the former Aqueduct Bridge, built about 1840) shows the excavation of the channel to be of quite different shape from that of the Susquehanna; it is flat at the bottom and only reaches to the depth of thirty-five feet from the surface. There was considerable "packing" by mud before the bridge was built, about thirteen feet thickness on an average. The cross-section of the river was considerably curtailed by the construction of the bridge. The river has tried to regain its former status and nearly succeeded in this effort, by removing the greater part of the

mud at its bottom. Supposing all the mud and artificial obstructions to be removed, the river could stand a lowering of its level of but eleven feet. Judging from surface exposures, the rocks at the bottom of the river are frangible or disintegrated gneiss, which is certainly less obdurate than the granite of the Susquehanna gorge, hence we have to conclude that the dislocation here is scarcely one-fourth of that of the Chesapeake Valley. At the site of the proposed Memorial Bridge, 1000 feet east from Easby's Wharf, rocky bottom is found at a depth of forty-four feet below the surface of the river; the stratum of mud here is about fifteen feet thick. At the Long Bridge, rock bottom has not been reached by boring or pile driving, and hard bottom in the Washington channel is seventy-one feet below the surface under a layer of sandy mud of sixty-nine feet thickness. The Georgetown channel has no mud at its bottom but runs over a hard bed of gravel and clay. A subsidence along the valley of the Potomac below Washington, inferior to that of Chesapeake Bay, is attested by the bay-like expansion of all the affluents at their mouths.

Subsidence in Delaware Bay.—I have not had the necessary time nor data at hand to make a similar inquiry about probable subsidence in Delaware Bay. In fact, we know Delaware River and Bay to have much stronger currents and to carry a greater amount of coarser sediment than Chesapeake Bay, and are prepared to find the traces of a former higher level less distinctly preserved. Nevertheless, we can trace a deep channel from the ocean into the middle of the bay where it is apparently choked off by alluvial deposits which fill up the entire upper part of the bay, leaving just enough room for the river channel. This "blind channel" has a depth of from twenty-two to thirteen fathoms, and is separated from the main river channel by shallow banks. The ebb-channel in actual use by the river has but a depth of three and one-quarter fathoms in its shoalest reaches. A comparison of our recent surveys with those made about fifty years ago proves that the high-water line, on the New Jersey side at least, has receded about one-eighth of a mile in the lower bay; but it would be rash to make subsidence responsible for this result. A comparison of the hydrographic surveys made about the same respective dates shows that there has been a great deal of shoaling going on in the interval, and it is not impossible that this shoaling has produced a disarrangement of the tidal elements, a retardment accompanied by an increase in amplitude which would show its effects on the high-water line.

Time of subsidence.—The evidence of a subsidence of the coast of New Jersey during the past century and yet in progress, collected by the late Professor Cook, must be consid-

ered as the main support of the theory which accounts for the existence of the submarine channel of the Hudson by submergence. In order to approximate the time of commencement of subsidence we have to take the evidence afforded by the latest Quaternary deposits. According to Mr. McGee* the clay terraces on which the city of Washington is built and which are supposed to be cotemporary with the first glacial invasion, indicate a submergence of about 150 feet during the period of their deposition. Hence it appears that the Lower Potomac and Chesapeake Bay with their depressed channels are of more recent origin. The borings at Fishing Battery cited above, which went to a depth of 140 feet and brought nothing to light older than alluvium, teach us that the deep channel of the Chesapeake must be of more recent date than any of the Tertiary and Quaternary deposits about the head of the bay.

The submarine border of the coast.—Returning to the subject of submarine channels, it has to be stated that diligent search has thus far failed to discover indications of such for either Chesapeake Bay or Delaware Bay, with the exception of a deep *cul-de-sac* of 396 fathoms inside of the bathymetric line of 100 fathoms, occupying nearly the same relative position to Delaware Bay as the cañon described above does to the Hudson.

In studying the geological changes in the sea bottom off the Middle Atlantic States, a remarkable fact should not be lost sight of. The sea bottom intervening between the submarine Hudson river channel and the coast of Long Island is characterized by its great regularity and smoothness, which can best be explained by assuming a gradual subsidence or an adjustment by superficial deposits. The bottom between the channel and the New Jersey coast, on the contrary, is distinguished for its ruggedness; great irregularities in the soundings give indications of shallow ridges and of cross channels, which go to prove that there was a periodical retrogression of the coast line, and that the sea keeps the conquered territory in very much the same condition in which it was found.

Greensand at the sea bottom.—The specimens of bottom collected during the recent survey of the approaches to New York, of which there are several hundreds at hand, show considerable quantities of black grains, described black specks on the charts, mixed up with the sand and mud of the entire region from Cape May to beyond Montauk Point; it is only in the mud of the gorge and of the deeper part of the continental slope that they are either scarce or missing. They are of spherical shape, of jet black luster, of brown color when fractured, and vary in size, with the fineness of the sand or mud, from the

* This Journal, vol. xxxv, May, 1888.

size of a pin-head to microscopical dimensions. They were evidently not composed of hornblende, and I hesitated to pronounce them greensand, which material Mr. Pourtalès, in 1869, reported to exist in the sands off Long Branch and Rockaway Beach.* Mr. McGee was kind enough to have an examination made in the laboratory of the U. S. Geological Survey and informs me "that the black grains are, as Count Pourtalès supposed, glauconite. The mineral seems to have undergone a curious alteration and the grains were polished through attrition and partly through chemic and mechanical alteration akin to that of nodulation, but the density, optical properties, hardness, etc., of the broken grains are identical with the like properties of New Jersey greensand from the Cretaceous and Eocene." It was an open question with Mr. Pourtalès whether these grains were washed out to sea from the marl beds of New Jersey or belonged to beds cropping out at the sea bottom. In view of the great extent of ground over which these grains are spread, and the great distance from the New Jersey coast, close to Montauk Point for instance, the first supposition can no longer be maintained; they must be treated either as belonging to marl beds laid bare by the sea or as the remnants of such which have been destroyed by the sea.† Whether these beds were Cretaceous or Eocene strata is a question which probably can only be decided upon paleontological grounds, but the preponderant strength of the Cretaceous on the mainland certainly speaks in favor of the latter having supplied the greatest amount of greensand grains to the ocean's bottom.

March 26, 1891.

ART. LX.—*Are there Glacial Records in the Newark System?* by ISRAEL C. RUSSELL.

SEVERAL expressions of opinion have been published by geologists in this country, respecting the existence of glaciers along the Atlantic border during the deposition of the rocks of the Newark system. It has been recently stated by Prof. J. D. Dana,‡ that this period "ended in a semi-glacial era, as is

* Appendix, No. 11, U. S. Coast Survey, Report of 1869, also Petermann's Geogr. Mittheilungen, vol. xvi, pp. 393–398.

† Quartz sand and pebbles, and greensand (perhaps hornblende) seem to be the only minerals which preserve their integrity in moderate depths at the bottom of the ocean; feldspar and mica are rarely found, and the so-called "mud" consists very often of the finest sand with some mica flakes, and with a just sufficient admixture of clay to produce cohesion.

‡ This Journal, III, xl, 1890, p. 436.

admitted by all who have studied the beds." As there is possibly not the unanimity of opinion among those who have studied the Newark system, that is suggested in the line quoted; it may be well to glance at the evidence on which those who consider that the period referred to contains glacial deposits or ended in a semi-glacial era, base their conclusions.

In describing certain coarse deposits on the eastern border of the Deep River area of Newark rocks in North Carolina, W. C Kerr* suggested that they indicate a sub-Newark glaciation: but these beds are considered as post-Newark by W. M. Fontaine.† A similar remark was made by N. S. Shaler and W. M. Davis,‡ in reference to the origin of the coarse conglomerate of the Newark system in the Connecticut valley. It has also been stated by J. D. Dana§ that the Connecticut valley had its violent floods during the Newark period, which may have been enlarged by the waters and ice of a semi-glacial era. But the most extended discussion of the possible glacial origin of certain coarse deposits in the Newark system has been made by W. M. Fontaine.† The arguments he advances are based on the following considerations:

First. The presence of coarse conglomerate and breccias. *Second.* Absence of fossil mollusks, radiates, etc. *Third.* Unexplained phenomena in the drainage and relief of the Appalachians, which are supposed to have been initiated by glaciers. *Fourth.* Extinction of the fauna and great change in the flora of the Atlantic border in the interval between the Newark and Cretaceous periods.

The evidence of glaciation according to Dana‖ "consists in thick deposits of stones and bowlders in which occur masses two to four feet in diameter, and therefore such as only ice could have handled and transported. They are situated along the west side of the area in Virginia, Maryland and New Jersey (where the dip of the Jura-Trias [Newark] beds is westward) and on the eastern in Connecticut and Massachusetts (where the dip is eastward).¶ Fontaine has found in Virginia and Maryland that they are the *later beds* of the formation." Exposures of Newark rocks north of Amherst, Mass., containing bowlders three to four feet in diameter are referred to, and Edward Hitchcock's conclusion that they are "the upper beds" of the series, cited. Coarse deposits near East Haven, Conn., are also mentioned.

* Rep. Geol. North Carolina, vol. i, 1875, p. 146.
† This Journal, III, xvii, 1879, p. 34.
‡ Illustrations of the Earth's surface, Glaciers. Boston, 1881, pp. 95, 96.
§ This Journal, III, xvii, 1879, p. 330.
‖ This Journal, III, xl, 1890, p. 436.
¶ Note in this Journal, III, xli, 1891.

Before examining the evidence, let us endeaver to determine what facts should be looked for, in case glaciers did invade the area in which Newark rocks were being deposited.

Preservation of Glacial Records.

All records of glaciation not buried beneath subsequent deposits, would certainly be destroyed by subaërial decay and erosion, during such a lapse of time as has intervened between the Newark period and the present day. Exception to this conclusion may, perhaps, be found in the changes which glaciers make in the drainage and topography of a region, but this matter is as yet little understood. Among the direct evidences of glaciation which might be preserved for indefinite ages, under suitable conditions, the following may be enumerated:

First. Smoothed and striated rock surfaces, if buried beneath fine sediments, might be preserved in their original condition; or casts of them might be taken, in the same manner that casts of footprints, showing the most delicate markings, have been preserved in great abundance in the Newark rocks themselves.

Second. Bowlders, smoothed, faceted and striated by glaciers (similar markings are also produced by river ice), might retain their records for indefinite periods, especially if they were imbedded in fine sediments or cemented by calcareous or other infiltrations.*

Third. When glaciers enter an estuary or a lake, moraines are deposited in unassorted or but imperfectly arranged, heaps about their extremities. The distance from the shore to which these deposits may be carried depends on the size of the glaciers and on the depth of the water they enter. A shallow estuary or lake could offer but feeble resistance to the advance of glaciers and might have moraines deposited widely over its bottom. On the other hand, glaciers entering a basin in which the water is as deep as the ice streams are thick, would have their advance checked abruptly and the moraines deposited would be confined to the borders of the basin; but scattered bowlders might be carried to great distances on floating ice. Should glaciers plow their way into shallow basins in which fine sediments were being deposited, it is evident that the beds beneath them might be greatly disturbed, while contortions would appear in adjacent strata owing to the unequal distribution of the load imposed on them.

* Since writing these pages, a paper has appeared by Dr. Hans Reusch, on "Glacial striæ and bowlder-clay in Norwegian Lapponie from a period much older than the last ice-age." *Norges geol. undersögelse aarbog for* 1891, in which descriptions are given of striated rock surfaces protected by morainal material containing striated and faceted bowlders. These records are thought to be of Cambro-Silurian age.

Fourth. The effect of a glacial period on animal and plant life has received much attention, but what records of the presence of glaciers at any special time might be expected in contemporaneous fossils, is still indefinite. A glacial period is usually considered as a cold period (the presence of local glaciers in mountainous regions, however, does not imply an Arctic climate). If a cold period followed a warm period, it is to be expected that migrations of fauna and flora would follow. Alternations of warm and cold periods would probably be accompanied by the extinction of many types. That changes of this character did take place during the Pleistocene glacial epoch, is apparently well established.

On the other hand, we know that luxuriant floras exist on the margins and even on the surface, of living glaciers of vast extent, which are not essentially different from plants of the same species growing at a distance from all perennial ice. In the present state of knowledge, it does not seem possible for paleobotanists to designate any group or assemblage of fossil plants which might not have flourished in proximity to glaciers.

While glaciers may be surrounded by a mild atmosphere, congenial to plant life, the waters into which they discharge either directly or after melting, are cold and could not be inhabited by animals characteristic of temperate or tropical climates.

It is to be expected, therefore, that sediments laid down in water into which glaciers are discharging could only contain the records of faunas, exclusive of land animals, characteristic of cold climates.

Weight of the Evidence.

Having in mind what records might reasonably be expected to occur in the rocks of the Newark system, providing glaciers had assisted in their deposition, let us see what the facts are:

First. No smoothed or striated rock surfaces either in the Newark system itself or on the floor on which it rests, have ever been found.

Second. No glaciated bowlders have been observed in the system.

Third. No scattered bówlders or large rock fragments indicating iceberg drift, have been found in the off-shore deposits.

Fourth. No Newark fossils indicating a cold climate, even in a remote way, have been discovered.

The paucity of molluscan life has been advanced as indicating Arctic conditions. It is well known, however, that mollusks and many other forms of life, inhabit the seas of northern regions close to where glaciers discharge. Shells occur also in

Pleistocene glacial clays. The evidence that glaciers are not necessarily accompanied by an extermination of mollusks in adjacent waters, is abundant. Besides, the hypothesis that mollusks are absent from the Newark sediments on account of glacial conditions, does not stand alone; other explanations of the same phenomena with many facts to support them have been advanced.

I have previously suggested that the great numbers of reptiles, some of them of gigantic size, the bones and foot prints of which occur in the Newark rocks, could not have lived in an estuary or lake into which glaciers were discharging and on which icebergs floated. Cold-blooded animals at the present time among which we must look for the nearest living allies of the "foot-print animals," are confined to warm regions; and there is no reason to suppose that this law of nature was reversed during the Newark period. The swarms of reptiles, both great and small, that lived at that time must have required an abundant food supply; this implies that the shores they haunted were more like those of Florida than those of Greenland at the present time.

The fossil plants of the Newark are Araucarians, ferns, equiseta and cycads. If these have any bearing on the question of climate they indicate sub-tropical and not Arctic conditions; although there is no reason why they might not have grown in proximity to glaciers.

In regard to the marked modifications in the flora and the extermination of the fauna of the Newark period, before the deposition of the next succeeding formation, referred to by Fontaine, we know that such changes have occurred at the close of each important division of geological history and may be accounted for in most cases by the imperfections in the records. Breaks in the life records invariably accompany breaks in stratigraphy. The assumption that these changes at the close of the Newark period were due to glaciation, is making an exception to a general rule, without facts to support it.

The Coarse Deposits.

It has been stated by Hitchcock and Fontaine, that the coarse deposits of the Newark system belong at the top. These statements lead Dana, as already cited, to the conclusion that the Newark period ended in a semi-glacial era. If the coarse deposit were confined to the top of the series, which as I shall show below, they are not, it would scarcely follow that they marked the close of the period, for the reason that deep erosion has unquestionably taken place.

But the coarse deposits are not confined to the top of the series. Wherever the base of the system is exposed it is almost

always found to be a coarse conglomerate or breccia. This deposit has been brought to the surface in several instances by faults and its character is well known. Coarse conglomerates occur especially on the east border of the Connecticut Valley area and on the west border of the New York-Virginia area and the detached areas in Virginia and North Carolina which fall in line with it. The beds are not continuous, but occur as local deposits. Where the coarse material is thickest, it grades into fine material both along the strike, that is along the shores against which it was deposited, and in a direction at right angles to the shore. Toward the center of the area of deposition, the coarse beds become fine and overlap or interdigitate, with fine off-shore sediments. As the upheaval of the system has not been uniform, erosion has cut far deeper in certain localities than at others. Thus, in northern New Jersey the Newark rocks are known to be not less than three or four thousand feet thick, while in the prolongation of the same area in Maryland, the thickness is certainly much less. The present base-level of erosion has cut deeper into the system at the south than at the north; yet all along the ancient shore, joining the two extremes, coarse deposits occur from time to time. The evidence points definitely to the conclusion that coarse deposits occur at all horizons from the bottom of the system up to the highest beds that now remain. If these beds are glacial deposits, then glaciers must have existed throughout the deposition of the system.

The coarse deposits along portions of the borders of the various Newark areas are always of local origin. They are not heterogeneous accumulations gathered from a broad area, as might be expected if they are of glacial origin, but have been derived from terranes in the immediate vicinity of where they now occur. The material forming the large bowlders in particular, may invariably be found *in situ*, near at hand.

No contortion of the fine sediments adjacent to or interstratified with the coarse deposits have been observed, such as would result from the extension of glaciers into the basins in which the fine sediments had been accumulated, or from the superposition or moraines upon them. On the contrary, the phenomena noted at many localities are fully explained on the assumption that the strata both coarse and fine, were deposited contemporaneously as water-laid beds.

The fine deposits intimately associated and even interstratified with the coarse deposits, are frequently ripple-marked, sun-cracked, and contain rain-drop impressions and the footprints of animals, at many horizons; thus showing conclusively, that the water bodies in which the strata were spread out were shallow. There is, therefore, no reason why glaciers

entering the basin should have halted at the immediate shore, and deposited their loads. Besides, the coarse deposits are not of the heterogeneous character typical of morainal accumulations, but are stratified and cross-bedded. It has been stated by those who claim that the deposits in question are of glacial origin, that they contain bowlders three to four feet in diameter, and therefore such as only ice could have handled and transported. My own observations have shown that bowlders either rounded or sub-angular, of the size indicated are not rare. Huge angular masses of rock like those to be seen on nearly every Alpine glacier, however, never occur. Those of my readers who have followed the Appalachian rivers south of the southern margin of the drift, will remember many instances where streams are encumbered with bowlders of even larger size than those mentioned above. These are being swept along by every flood, and did the streams empty into lakes, would be deposited in shore conglomerates. It may be remarked also, that river ice might have assisted in the movement of the Newark bowlders, without supposing the existence of glaciers.

After reviewing the voluminous literature relating to the Newark system and personally examining nearly every area occupied by it, I fail to find any evidence to support the hypothesis that glaciers assisted in its deposition. That there may have been glaciers on the Appalachians previous to or during the Newark period, is within the bounds of possibility, but as yet there is no evidence in this connection on which to base an opinion; we can only say that if they were present during the period under discussion, they did not reach the estuaries in which sediments were being deposited.

Washington, D. C., Feb. 15, 1891.

Art. LXI.—*A reply to Professor Nipher on "The Theory of the Solar Corona"*; by F. H. Bigelow.

In the Report of the Washington University Eclipse Party, on the Total Eclipse of the Sun, January 1, 1889, Professor Francis E. Nipher makes a criticism of my paper on the Solar Corona published by the Smithsonian Institution, 1889. The theory which I have proposed is of itself sufficiently technical in a mathematical sense, not to be burdened with an inaccurate or irrelevant criticism, and I therefore wish to make the three following observations on Professor Nipher's Report.

1. The mathematical *non sequitur* of the work on pages 22, 23 is so obvious as to need no special comment. I am informed that the equation for the line of force which should follow

from the equation of the force at any point, $F=\frac{\varphi a^3}{R^3}(3\cos^2\omega+1)^{\frac{1}{2}}$, is not what he intended to have appear. Instead of reading, $N=\frac{2\pi\varphi a^3}{R^3}(3\cos^2\omega+1)^{\frac{1}{2}}(1-\cos\omega)+\varphi\pi R^2\sin^2\omega$, it should read, $N=\frac{2\pi\varphi a^3}{R}\sin^2\omega+\pi\varphi R\omega^2\sin^2\omega$. The equation in its corrected form gives two terms, the first, $2\pi\varphi a^3\frac{\sin^2\omega}{R}$, which is identical with that employed by me in my paper, and the second, $\pi\varphi R^2\sin^2\omega$ which Mr. Nipher ascribes to the action of a uniform field of force surrounding the Sun.

2. At this place the ways part, and the irrelevant criticism begins. The equation in N with one term represents a certain condition of things; the equation in N with two terms is a different case and belongs to another state of things. If anyone is curious to see the two cases fully represented graphically, let him turn to Maxwell's Electricity and Magnetism, vol. i, fig. 5, Art. 143, for the first, and to vol. ii, fig. 15, Art. 434, for the second. Professor Nipher is at liberty to ascribe the second case, as his own, to the conditions about the sun, but there is no need to dedicate it to my theory, because it was not employed by me. There is no evidence that the sun is placed within a field of uniform force, produced outside of itself, nor is it necessary to resort to such a supposition in order to account for the forms of the coronal streamers, as seen from the earth.

When we come to consider the earth the case is different from that of the sun, since we have some reasons for thinking that the earth lies in a uniform field, generated by the action of the sun upon the earth. As I pointed out in the same paper it may be necessary to treat the field surrounding the earth by the full equation, written by Professor Nipher. I have published a theory for doing so, employing the configuration of the auroral streamers, if suitable observations can be obtained; [this Journal, February, 1891.]

3. It must be perfectly understood by students of this subject that most of the mathematical devices for discussing the field of force surrounding a polarized sphere, are physical fictions. There are many such devices, as for instance: (1) two equal masses of electricity with opposite signs placed infinitely near together at the center of the sphere, (2) the cosine distribution from a maximum superficial density at the axis, (3) the polarized sphere or the layers of gliding, (4) an indefinitely small magnet at the center of the sphere, and others. From such suppositions the mathematical treatment builds up the

observed lines of force surrounding the sphere. That there might be no doubt about my own position on the subject, I arrived at the formula for the lines of force by the geometrical and also by the harmonic analysis, never imagining that a critic would convert this common mathematical process into a physical reality of the sun's constitution. We are now interested to discover an analytical expression for the curvature of the coronal streamers; their physical nature is another question, one which is at present beyond our knowledge; it shares the perplexity attending any discussion of electrical or magnetic action. This then is the second irrelevant criticism. I did not suppose that the cosine distribution of electricity was actually plastered over the surface of the sun, and there was no need to allude to this point. Professor Nipher quotes me as saying, "on the supposition that we see a phenomenon *similar* to that of free electricity," (p. 21.) If the presence of the word "similar" was not sufficiently explicit as to my meaning, he should have quoted from page 19 of my paper as follows: "We have avoided speaking of the apparent coronal structure as a phenomenon of electricity, in deference to the doubt that free electricity can exist at such high temperatures on the sun's surface, but have shown that some force is present acting upon the corona according to the laws of electric potential." No one can at present explain the physical constitution of the matter that produces the coronal streamers, but I have in my work endeavored to show that they coincide in direction with stream lines produced by matter obeying the Law of the Newtonian Potential Function in the case of Repulsion. Such evidence as has been acquired to exhibit this identity of form between the coronal lines and the theoretical lines is now being published. [Proc. A. S. P., No. 16 or No. 17, and this Journal, July, 1891.]

Washington, April 29, 1891.

ART. LXII.—*On the recent Eruption of Kilauea;* by W. T. BRIGHAM.*

I PRESENT herewith my report on the changes that have taken place in the crater of Kilauea during the past month.

The last week of February, I found the crater in a state of intense but not extensive activity. During the seven months that had elapsed since my last visit, the depressed area of 1885 had been filled to a height of nearly 150 feet, and there were

* Report to Prof. Wm. D. Alexander, Surveyor General, dated Honolulu, H. I., April 8th, 1891.

indications that the entire floor of the crater, which has long been domed, had been elevated to some undetermined extent. One indication of this was seen in the great crack which extends across the trail near the eastern edge of the crater. This crack had closed nine inches.

The peaks that have long been an interesting feature of the fire area, as well as a land mark for the whole crater, had risen with the tide, and now towered at least 200 feet above the pools of liquid lava at their feet. Seen from the Volcano House, one-third of their total height was above the outer western wall. Their structure was loose, and so much smoke or sulphurous fumes escaped from almost their entire surface that it was not safe to attempt the ascent. On all sides they were surrounded by cones, generally hot and ejecting lava spatters. These cones were, in at least two cases, high up on the side of the main peaks, and exactly resembled the "Hornitos" of Humboldt. Several of the cones could be approached closely enough to throw blocks of lava into the oven door. One large cone of a group of three had become extinct, and one-half had fallen in fragments, showing the smooth inner walls, and the exceedingly superficial nature of its action. The wind was southerly, and it was therefore easy to go to the south and west of the fire area. Southeast of this was an extensive lava flow, covering some six acres, and proceeding from the base of a cone. To the southward of this a previous flow had formed a high ridge of "*a-a.*"

West of the peaks was the most active portion, while in July the active lake was on the southeast side. The northern pool was the largest, of an irregular shape, having a promontory extending a third of its diameter from the middle of the western side. Its diameter, north and south, may have been 250 feet, and the banks were of unequal height but averaged fifteen feet above the lava surface. The next pool was the smallest, but the most active, and was 500 feet south of the first. Its diameter was less than one hundred feet, but the banks were overhanging. The third pool was near the last and intermediate in size.

All these pools were seemingly on a level, and were in my opinion connected; the crust intervening being not more than fifteen inches thick, and quite hot, although all the neighborhood was covered with a thick coating of "Pele's Hair," a good non-conductor. The usual intermittent action was no longer there: the surface had no time to cool, and no crust was allowed to cover the surface. From all the pools spatters of considerable volume were thrown on to the surrounding banks, and the direction of these jets was very peculiar. The molten lava was thrown obliquely, and the bright matter de-

scribed figures not unlike an interrogation point; the plane of these figures was quaquaversal.

There was remarkably little sulphurous vapor, and the absence of steam would have puzzled those geologists who impute to its agency the volcanic action. Outside of the crater, however, steam was issuing in several places; among these, the top of the wall near the Kau trail; the eastern wall between the two lateral craters; and the depressed wall between the main crater and Kilauea-iki.

As we left the pools in the evening, it was noticed that a cone some fifty yards west of the southern lake was sputtering in a very excited manner, and at 2 o'clock the next morning we saw it from the house spouting lava to an estimated height of twenty-five feet, while detached spatters were thrown twice that height. At 8 o'clock, when we left the crater, the fire fountain was still bright in the full morning light. It seemed to flow as freely as an uncapped artesian well.

This was nearly the condition of the crater a week later, when on March 6th, 1891, at 9.30 P. M. a slight earthquake was felt at the Volcano House, and the cones settled slightly. The next morning the peaks were out of sight. At Punaluu stronger earthquakes were felt, and at the Half Way House, the ground was in a continual tremor for some time; 300 shocks were counted in one night, but no accurate record was kept.

On the 2d of April, at your request, I visited the crater again and found the following condition of things. From the house the absence of two landmarks,—the peaks and the column of smoke, was at once noticed, and as night fell the accustomed look toward Halemaumau met not the slightest glimmer of light; all was as cold and dead as the grand old dome of Mauna Loa ten thousand feet above it.

The next morning the yawning pit was clear cut as seen from the house, and only a pale bluish smoke arose from its lips. Beyond, to the southward, was a white smoke that rose and fell, but was not of considerable extent. On descending into the crater the crack was found unchanged. Many smaller cracks intersected the trail, especially towards the middle of the crater, but the condition of the stone monuments on the Rock called the "Half Way House" showed conclusively that there had been very little disturbance in the crater itself: not one of the stone piles had been upset. The lava flow noticed on the previous visit was still warm, and on the borders of the depression was red hot. The entire fire area was gone. Peaks, cones and pools had vanished, and in their place was a pit

crater of elliptical outline, 2500 by 3000 feet, the major axis being nearly east and west. The walls were perpendicular and quite impassable. The estimated depth was 500 feet. There were many concentric and radial cracks making it dangerous in many places to approach the edge. Almost all the smoke proceeded from the hot upper crust of the border, none came from the bottom; and while every portion of the pit was clearly seen, the heated air constantly rising from the border made photographing a partial failure. Portions of the cracked lips had sunk, leaving steps toward the pit. There was a complete absence of any black in the walls or bottom; all shades of brown, red and yellow, but generally light: not in the least dismal or fresh looking, except for size, it looked quite like Mokuaweoweo, and might have been as old. The walls were in remarkably even layers; no cavities, dikes or great irregularities were to be seen. It was a wall of masonry whose cement time had crumbled, and it would hardly have seemed out of place had some vine trailed its festoons down the courses. The bottom was a confused mass of lava blocks of the same color as the walls, and was deeper at the west side. The impression was that the top of the peaks was there.

Owing to the bad arrangements of the Inter-Island S. N. Co. we were hurried away at daybreak the second morning, and so had no opportunity to photograph from the western wall, nor to take the desired measurements. The location is however settled with sufficient accuracy as the whole area covered by the last break-down and the pool to the eastward as well.

No word could be heard of any surface flow "*makai*" (seaward) of the crater, but from the steamer as we left Punaluu Saturday afternoon, a dense smoke was seen midway between Kilauea and the sea, which might have been a forest fire, or an outbreak.

It is useless to speculate as to the return of the fires: the present condition of the pit precludes any approach to them were the bottom dotted with fire-pools. In 1886, the wall was sloping on one side at least, affording access to the bottom. Any earthquakes may however topple down enough of the present wall to make a descent possible and the fires may be visible in a week or not for months. In its present condition Kilauea is most interesting to geologists, as in the walls of its included pit is an epitome of the formation of the mountain itself, a clean-cut section of 500 feet.

ART. LXIII.—*Turquois in Southwestern New Mexico;* by CHARLES H. SNOW.

SOME years ago excavations of ancient origin, the object of which was unknown until recently, were noticed in the Burro Mountains, southwest of Silver City, in Grant County, New Mexico. During the past year, Mr. W. J. Foley, then of Silver City, received a letter from a firm of Indian traders, in which it was stated that the Navajos claimed that turquois existed near Silver City, mines being described as having been worked at some remote period in an extensive, though primitive, manner. A search, thereupon instituted by Mr. Foley, resulted in an apparent connection between this story and the ruins above noted.

The locality has since been visited by the writer, who found the excavations situated upon several adjoining hill slopes. Although extending over considerable territory, they occur in isolated groups, and do not convey the impression of any very extended single effort. The size and character of the waste piles seem rather to indicate shallow works, although at one point a shaft or deep pit existed, and at another, close by an abruptly rising hill, either a shaft or a tunnel into the hill. All adits have long since been obliterated, and the piles of debris are more or less concealed by vegetation. The waste rock is in large pieces, and was evidently mined by the most primitive methods. It consists of gray quartz with white cleavable feldspar unlike that at the locality next described. Turquois was found in occasional small pieces attached to or seaming the rock, the color being the same pea-green shown by the "Los Cerillos stone." No metallic matter was noticed.

Continued search by Mr. Foley resulted in the location of another claim, about a mile distant from the one mentioned above, and near the "Chief of the Burros" copper mine, not now worked. There exists here a test pit, sunk some years ago as a copper exploration, the veins of turquois having been, strange to say, mistaken for veins of ores of that metal. The pit has a dimension each way of about three feet. It is upon the summit of a dike of a buff-colored rock traceable for some at each side of the pit. The dike matter, as seen in the pit and at one or more places upon the surface, contains a perfect network of turquois. The layers are from a line to an eighth of an inch in thickness, frequently starting in a thick layer, and then forking into several finer ones, which again subdivide. Where the layers are thick, a tendency of the rock to cleave away at the line of contact was sometimes, but not always,

noticed. The layers occasionally had an abrupt lateral termination, like the edge of a volume of thick fluid poured upon a flat surface.

Besides the layer formation, turquois was also noticed in small dots and in isolated patches, which occasionally differed from the vein matter in being of a more bluish shade. The prevailing color, however, was the green, common to the American turquois, and typified at Los Cerillos.

Turquois is known to occur at two other points in Grant County, New Mexico, both of them in the Burro Mountain district. From one of these the writer has specimens, consisting of sheets of very thin turquois having several square inches of surface area and from which gangue matter similar to that at the locality near the copper mine has been entirely removed by decomposition.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *On the Compressibility of Hydrogen, Oxygen and Nitrogen.*—Amagat has subjected hydrogen, oxygen, nitrogen and air to pressures varying from one hundred to one thousand atmospheres, at temperatures of 0°, 100° and 200°. He finds that for hydrogen the values of dv/dt are practically independent of the temperature, the coefficient of expansion diminishing regularly as the pressure increases; while for nitrogen, oxygen and air, this coefficient passes through a maximum corresponding to the pressure at which the product pv has its minimum value. The values of dp/dt for hydrogen are also practically independent of the temperature, and nitrogen and air resemble hydrogen in this respect. Indeed the properties of hydrogen seem to be limiting values toward which those of all other gases tend; these limiting values of dv/dt and dp/dt being independent of the temperature, the former diminishing and the latter increasing as the pressure rises, the change being regular in both cases. At pressures up to 3000 atmospheres and at all temperatures, the isothermal lines have been shown by later experiments not to be exactly straight lines but to have a slight concavity toward the axis of abscissas.—*C. R.*, cxi, 871; *J. Chem. Soc.*, lx, 378, April, 1891. G. F. B.

2. *On Osmotic Pressure.*—In 1888, an analogy was pointed out by van't Hoff between the physical condition of a substance in dilute solutions and in the gaseous condition, osmotic pressure in the former case being the analogue of vapor-pressure in the latter. Boltzmann has now investigated osmotic pressure mathematically from the standpoint of the kinetic theory of gases. He supposes a cylinder, having a semi-permeable septum in the middle dividing it into two equal parts, and having its ends

closed by pistons. One of the compartments thus formed is filled with a dilute solution, the solvent of which alone can pass through the septum. The other compartment is filled with the solvent only. Osmose takes place, the solvent entering the solution through the septum and increasing the pressure exerted by that solution; the flow continuing until the osmotic pressure is balanced by the pressure within the vessel. By varying the pressures upon the pistons, equilibrium may be produced, and the osmotic pressure measured. The author proceeds to treat this osmotic system, with reference to the forces in operation in its various parts, in the same manner in which the problem would be discussed with reference to the kinetic theory of gases. And he finds in this way, that the resultant of all the forces in the two compartments which produce pressure on the septum, *i. e.*, the osmotic pressure, is equal to the gaseous pressure which the dissolved substance would exert were it distributed as a gas throughout the volume occupied by the solution, assuming that the mean kinetic energy of a dissolved molecule is equal to that of a gaseous molecule at the same temperature.— *Zeitschr. physik. Chem.*, vi, 474; *J. Chem. Soc.*, lx, 389, April, 1891. G. F. B.

3. *On the Production of Electrification in the Preparation of solid Carbon dioxide.*—In order to obtain rapidly and conveniently a considerable quantity of solid carbon dioxide, HAUSSKNECHT fastened over the jet of a wrought iron cylinder containing the liquid dioxide, such as is found in commerce, a bag of coarse linen cloth. By inclining the cylinder, the liquid issues under a pressure of 60–80 atmospheres, and in expanding into the gaseous state, absorbs so much heat as to solidify a portion of the escaping liquid, this solid collecting in the bag in the form of a compact snow. If the bag be made of strong canvas and have a capacity of from one to two liters, and if the experiments be conducted in the dark, it will be observed that the bag is filled with a greenish-violet light and that electric sparks from 10 to 20^{cm} long issue from its surface. If the hand be placed in these sparks the same peculiar prickling effect is noticed as when it is brought near the collector of an electric machine. This appearance of electrification is especially noticeable where imperfections occur in the compression pump or in the valves or manometers, so that the carbon dioxide issues under great pressure. The cause of this development of electrification is no doubt similar to or identical with that which operates in the hydro-electric machine of Armstrong. The liquid issuing with great force is converted into gas at once when it reaches the air. But under so great a pressure and at so low a temperature, the gas thus forced through the openings in the bag is accompanied by fine particles of the liquid, and probably of the solid also; the friction of these solid and liquid particles developing the electrification. For the success of this experiment it is essential that the carbon dioxide be absolutely free from air. The luminous phenomena in the interior of the bag appear first when the solid

dioxide has formed a layer of from half a centimeter to a centimeter in thickness. The author is continuing his investigations upon these phenomena.—*Ber. Berl. Chem. Ges.*, xxiv, 1031, April, 1891. G. F. B.

4. *On the Molecular Formula of Hydrogen Fluoride.*—PATERNO and PERATONER have determined the molecular mass of hydrogen fluoride by means of the lowering of the freezing point which it produces, the apparatus being the one ordinarily employed for this purpose, except that it was made entirely of platinum. The thermometric vessel was contained in a platinum tube, closed at its lower end and extending nearly to the bottom of the apparatus, being fastened to the cover. The space between the thermometric vessel and the walls of the tube was filled with mercury. After a series of comparative experiments proving this apparatus to give results coinciding with those obtained with a glass apparatus, it was applied to the determination of the molecular mass of hydrogen chloride in aqueous solutions of various strengths; and the results led uniformly to the formula HCl. On repeating the experiments with hydrogen fluoride however, the molecular mass obtained corresponded always to the doubled formula H_2F_2. Whether for more dilute solutions still this double molecule will split into two simple ones, farther experiments must determine. This result confirms the conclusion reached by Mallet by the vapor density method.—*Ber. Berl. Chem. Ges.*, xxiv, (Ref.) 298, April, 1891. G. F. B.

5. *On the Extraction of Oxygen from the Air.*—KASSNER has recently given further particulars concerning his process for extracting oxygen from the air on a commercial scale, based on the successive formation and decomposition of calcium plumbate. He now finds that in producing this plumbate, it is better to use a slight excess of calcium carbonate, say five per cent. Two molugrams (a molugram is the molecular mass in grams) of calcium carbonate, with this excess, is heated with one of lead oxide; and a resulting spongy product is obtained in this way, in which nearly the whole of the lead oxide is converted into the plumbate. The calcium carbonate is used in the form of limestone and it has been found unnecessary to stir the materials during the heating, which may be effected in an ordinary reverberatory furnace well supplied with air. To recover the oxygen the author heats the calcium plumbate in the presence of carbon dioxide, when the following reaction takes place:

$$Ca_2PbO_4 + (CO_2)_2 = (CaCO_3)_2 + PbO + O.$$

So that the process is a continuous one, the quantity of oxygen obtainable from a given quantity of charge being unlimited. Since the formation of the plumbate requires only a few minutes, and since its decomposition by the carbon dioxide is complete, the author thinks this process preferable to those of Boussingault and Brin; especially since the value of the material, the cost of the plant and the working expenses are extremely small.—*Dingl. J.*, cclxxviii, 468; *J. Chem. Soc.*, lx, 392, April, 1891. G. F. B.

6. *On Sodium-amine and Di-sod-ammonium chloride.*—JOANNIS has observed that at ordinary temperatures, sod-ammonium slowly decomposes into hydrogen and sodium-amine (sodamine); this decomposition tending toward a limit determined by the pressure of the hydrogen evolved. The sod-amine, NH_2Na, appears in small colorless transparent crystals; while that noticed by Gay Lussac was amorphous and of a blue or green color. The crystals dissolve in water with a hissing noise but without the evolution of gas. Disodium-ammonium chloride, NH_2Na_2Cl is an unstable compound which is obtained, mixed with sodium chloride, when sodium is treated with an excess of sodium chloride in presence of liquefied ammonia, insufficient in amount for complete solution of the salt. On washing with liquid ammonia this compound decomposes into sodium chloride which dissolves and into sodamine which is left. By water it is broken up into ammonia, sodium hydrate, and sodium chloride.—*C. R.*, cxii, 392; *Ber. Berl. Chem. Ges.*, xxiv, (Ref.) 292, April, 1891. G. F. B.

7. *Velocity of electrical waves in insulating fluids.*—Maxwell has shown that the relation $n^2 = \mu$ is a consequence of his electromagnetic theory of light. In this formula n is the rate of the velocity of the wave in a vacuum to that in the substance examined and μ is its dielectric constant. L. ARONS and H. REUBENS, employing Hertz's method of studying electromagnetic waves, have examined the relation given by Maxwell and find it very nearly fulfilled in the case of the four fluids investigated by them.—*Ann. der Physik und Chemie*, No. 4, 1891, pp. 581–592.

J. T.

8. *The telephone in an optical apparatus for measurement of electrical currents.*—MAX WIEN employs the movement of the telephone diaphragm to measure both constant and alternating currents and prefers this instrument to the usual form of dynamometer. The iron diaphragm of the telephone is replaced by a thin metallic plate similar to those used in aneroid barometers. A piece of iron is placed upon this diaphragm opposite the pole of the telephone magnet and the movement of the diaphragm is communicated by a simple lever arrangement to a small mirror, which deflects the excursions of a spot of light into the field of view of a telescope. The amplitude of the movement of the spot of light is a measure of the current strength. The author discusses the accuracy of the indications and shows that quantitative results can be obtained by this simple instrument.—*Ann. der Physik und Chemie*, No. 4, 1891, pp. 593–623. J. T.

9. *Photography of the ultra red rays.*—In a communication to the Royal Society, March 12, Mr. GEORGE HIGGS stated that the alzarine blue S possesses in a high degree sensitive giving properties for rays throughout the region comprised between wavelengths 6200 and 8000, and does not like cyanin lower the sensitiveness to the violet and ultra violet. The method of preparation of the alzarine was described. With a slit 1/1000 inch in width and an exposure of forty minutes results have been obtained in the

region of great A of the second order, which possess all the detail and definition usually so characteristic of the violet end.—*Nature,* April 2, 1891, p. 525. J. T.

10. *Lecture experiment on magnetic screening of conducting media.*—J. J. Borgman describes the following experiment. A Lecher's tube (Ann. der Physik und Chemie, xli, p. 850) is put by means of two cork rings into another large (4 cm. diam.) glass tube, with a crane on one end. Holding the tube in one hand, and approaching it to a wire in which electrical waves are produced, a continuous lighting of the tube is seen. If the outer tube is filled with dilute sulphuric acid the light disappears. This is not the case when the outer tube is filled with water.—*Nature,* April 23, 1891. J. T.

II. Geology and Natural History.

1. *Eruption of Kilauea.*—The Daily Pacific Commercial Advertiser of April 30th reports the following additional facts: "The breakdown is slightly larger than the one of 1886. It also differs from the one of 1886 in the following respects: in 1886 the fire appeared to have entirely gone out, there seemed to be little steam left, and for three months the crater was absolutely dead and cold, with the exception of the still warm lava which had run out prior to the breakdown. The lava then came back slowly, and it was considerably over a year before the whole basin filled up again. The breakdown of 1891 left hot lava still to be seen in the cracks around the edge of the breakdown, and dense clouds of vapors, steam and intense heat arising at several points from the bank. After a lapse of only three weeks the molten lava again appeared in the pit, and it is now filling up rapidly. The news brought by the steamer W. G. Hall was that up to the 26th inst. the bottom of the pit had filled up about 100 feet, and a lake of liquid lava formed some 250 to 300 feet in diameter. This is the result of only ten days' action. The bottom of the pit was steadily rising and the size of the lake increasing, and activity showing itself at new points every day. The illumination was very bright, being visible at night at Punaluu, thirty miles away."

2. *Geological Survey of Ohio.*—First Annual Report under the third organization by Edward Orton, State Geologist. 330 pp. 8vo.—This very valuable report, chiefly by Professor Orton, treats of the origin and accumulation of mineral oil and natural gas, and of the Trenton and Clinton limestone and other rocks in Ohio, as sources of these materials. The chapters on these topics are preceded by one on the general geological structure of Ohio. The report is accompanied by two maps of the oil fields and gas fields. It closes with a chapter on the measurement of natural gas in gas wells, pipe lines, etc., by S. W. Robinson.

3. *Iron Ores of Minnesota by* N. H. Winchell and H. V. Winchell. Bulletin No. 6 of the Geological Survey of Minnesota, 420 pp. 8vo. With a geological map, 44 plates and 26

illustrations in the text. Minneapolis, 1891.—This volume treats, as the title-page further states, of the geology, discovery, development, qualities and origin of the ores, and of comparison with those of other iron districts. The rocks are described with some detail, colored microscopic sections given of several of them, and the age of the deposits is discussed at length. One of the interesting plates of the volume represents the famous Greenland mass of iron found embedded in basalt and weighing 19 tons, now in the museum of the Royal Academy at Stockholm.

4. *The Tertiary Insects of North America;* by SAMUEL H. SCUDDER, U. S. Geol. Surv. of the Territories, F. V. Hayden. Vol. xiii, pp. 734, Plates I–XXVIII. Washington, 1890.—This volume brings the subject of fossil Tertiary insects into prominence as a department of American paleontology. Formerly, it was impossible to make any general comparison between the American and European faunas, as the former was meager both in specimens and species. Owing to the rapid geological exploration of the West, and to the labors of the author of this monograph, the lack of material and of definite knowledge have both been removed. Moreover, as the insect-bearing rocks are so extensive, and have been investigated at so few localities, it is evident that further researches will result in a richer and more varied fauna than has yet been developed elsewhere.

Six hundred and twelve species are described, divided among the orders as follows: Myriapoda 1, Arachnida 34, Neuroptera 66, Orthoptera 30, Hemiptera 266, Coleoptera 112, Diptera 79 Lepidoptera 1, and Hymenoptera 23. By far the most abundant fauna occurs in the Tertiary lake basin at Florissant, Colorado. Some of the higher orders of insects are more fully represented than is indicated in the enumeration of species. Their description is reserved for the acquisition of more and better material. Other localities yielding fossil insects and included in the volume are: Green river, Fossil and Horse Creek, Wyoming; the vicinity of Quesnel, British Columbia; Scarboro, Ontario; and Port Kennedy, Pennsylvania. C. E. B.

5. *Trilobites of the Upper Carboniferous of Kansas.*—The Kansas City Scientist—a popular scientific monthly of 16 pages 8vo, made the official organ of the Kansas City Academy of Science—contains, in its March number, an article by S. G. Hare on species of Phillipsia, illustrated by a plate; and the February number contains an account of foot-prints from the Upper Carboniferous, by E. Butts.

6. *An Introduction to the study of Petrology: The Igneous Rocks;* by FREDERICK H. HATCH. 128 pp. London and New York, 1891 (Swan Sonnenschein & Co.; Macmillan & Co.) This little book will be found useful by those desiring a concise account of the minerals which are present in the various types of igneous rocks and of the composition and occurrence of these rocks themselves. The space is about equally divided between these two parts, and the descriptions are probably as satisfactory as is possible where the subjects are treated with such brevity.

7. *Sinopsis Mineralógica ò Catálogo descriptivo de los Minerales por* CARLOS F. DE LANDERO. pp. 1–432. México, 1888. This is an alphabetical list of the various mineral species, giving brief descriptions with also numerous synonyms. It will be useful not only at home but wherever a knowledge of the Spanish and local Mexican names of minerals is needed.

8. *New Meteorites.*—Mr. Edwin E. Howell gives descriptions of a number of new meteorites in vol. i of the Proceedings of the Rochester Academy of Science, illustrated by figures (part of which have been used in this Journal, vol. xl, p. 223). They are named the Welland Meteorite, from Welland, Ontario, Canada; the Hamilton County, from Texas; the Puquios, from Copiapo, Chili; the De Cewsville, from Ontario, Canada; two from Atacama, Chili, called the Doña Inez and the Llano del Inca; and from Chili three others, the El Chañaralino, la Primitiva and the Calderilla. The Hamilton County meteorite weighs 179 lbs., and its largest diameter is 17½ inches. A fine plate printed from the iron exhibits grandly the Widmanstätten figures.

9. *Die Protoplasmaverbindungen zwischen benachbarten Gewebeselementen in der Pflanze;* by F. KIENITZ-GERLOFF. (Bot. Zeit., 1891, Nrn. 1–5, Taf. I–II).—The continuity of protoplasm in adjacent cells of vegetable tissue has since its discovery been a subject of the greatest interest and significance. Through this new and unexpected feature of plant-anatomy it has been hoped that light might be thrown upon a host of physiological processes hitherto unexplained; and the importance thus attached to the histological fact has very naturally made the subject an alluring one for original investigations. Perhaps, indeed, no point of plant-anatomy has so often, within the last few years, been chosen as a subject for special study, nor in most cases proved so barren of new results. Since the appearance of Gardiner's papers a number of new instances of the phenomenon in question have, it is true, been observed and recorded. Few details, however, have been added to our knowledge of individual cases, nor have the methods employed in the treatment and staining of preparations been essentially improved. Russow's highly interesting hypothesis that the threads uniting the protoplasm in adjoining cells arise from the delicate fibrillæ observed between the nuclei in cell-division, has been neither confirmed nor refuted; and in regard to the physiological significance of the continuity of protoplasm theories are as conflicting as ever. The present paper by Kienitz-Gerloff, treating the subject both in its anatomical and physiological aspects, is therefore especially welcome.

After a brief historical sketch the author proceeds to consider the different ways of treating sections to bring out clearly the connecting threads of protoplasm, and states that he has met with the best success by placing sections of fresh material in a solution of potassic-iodide to fix the protoplasm with but little contraction, before such reagents as sulphuric acid or chloriodide of zinc are employed to act upon the cell-walls. This is

Terletzki's modification of the earlier methods. In the case of succulent plants it was found advantageous to dip the parts to be sectioned in boiling water and then harden them in absolute alcohol. As a coloring agent Hoffmann's aniline blue was chiefly employed, but the combination of this staining agent with picric acid, so highly recommended by Gardiner, was found to give too faint a tint—an experience we believe, which has been shared by others. Especial difficulty was found in coloring, where the cell-walls were cutinized, and in such cases a strong solution of methyl-violet gave the most satisfactory results. As a mounting agent glycerine proved useless, while Damar and Canada balsam are recommended.

In a systematically arranged list the author enumerates some sixty species, from the *Hepaticæ* upward, which have been investigated by him, and indicates in each case the elements between which protoplasmic threads were observed. As the tissues in and between which the continuity of protoplasm has been detected embrace nearly every kind of histological element, the conclusion—already stated by others upon a less secure basis of observation—is drawn that all the elements in the higher plants are so connected. A single exception, however, is made in the case of the guard-cells of the stomata, the walls of which according to Kienitz-Gerloff are entirely free from perforating threads.

The morphology and origin of the threads are excellently discussed and the phenomena observed are well illustrated in a number of figures. Details of course cannot be given here. It may be mentioned that the spindle-shaped enlargements of the protoplasmic threads, so frequently observed near their middle but not altogether confined to that region, are plausibly explained on the ground that some of the lamellæ of the cell-walls, notably those near the middle, are much less strongly swollen than others by such reagents as sulphuric acid, and therefore exert less pressure upon the penetrating threads. The protoplasm accordingly remains in greater quantity at these points. Our attention is also called to the fact that the connecting threads as they exist in nature, are doubtless much larger than they appear after treatment with reagents employed to bring them into view. Both the morphological descriptions and accompanying figures render Russow's theory, just mentioned, very doubtful. Its disproof however is not altogether conclusive.

Of especial interest is the treatment of the physiological aspect of the continuity of protoplasm, and here Kienitz-Gerloff favors strongly the theory of Kohl and Wortmann, that a transference of protoplasm and the substances it contains really takes place from cell to cell by means of the threads. This view has been opposed by various observers, most recently by Noll and Zimmermann, who are inclined to consider the function of the continuity rather the communication of shock or impulse. Of the several very plausible reasons which Kienitz-Gerloff gives for believing that a transference of matter is effected by the structures in

question we may only mention a curious negative argument from the guard-cells of stomata. In the autumn, as is well-known, the organic contents of the cells in deciduous leaves retire in great part into the stem, but in the guard-cells alone the protoplasm remains in tact even after the fall of the leaf. As we have just seen, these are the only cells which possess no protoplasmic connection with the other elements, and the inference is easy that this is why their contents are not withdrawn. Reasoning from the converse it appears probable that the connecting threads among the other elements are the structures active in removing the organic substances from cell to cell, and finally out of the leaf into the stem. These facts taken alone would have but little weight but in conjunction with various other phenomena furnish a particularly interesting bit of evidence. The article closes with an excellent bibliography of the subject. B. L. R.

10. *Protoplasmaverbindungen bei Algen;* (Berichte der deutsch. bot. Gesellsch., ix, pp. 9–16).—In a paper of this title Dr. F. G. Kohl describes a series of observations upon the continuity of protoplasm in various cryptogams ranging from the *Conjugatæ* to the ferns, thus neatly supplementing the work of Kienitz-Gerloff just discussed. Kohl's methods of bringing the connecting threads to view are very interesting, since they are novel as applied for this purpose. Instead of using some reagent to act upon the cell-wall, he produces a slow plasmolysis, employing a solution of tannin-anilin (as recommended by Loeffler to show the cilia of bacteria), and then, after staining the preparations, employs dilute glycerine to remove the coloring matter from the cell-walls. The well-known *Spirogyra*, which has been studied from so many different points of view, is once more made to do service as a typical example, and the continuity of the protoplasm in adjoining cells of its filaments is described and figured in detail. Kohl states further that he has observed similar phenomena in *Cladophora, Ulothrix* and other related forms. While in some of the algæ, notably in certain *Florideæ* the continuity of the protoplasm can be very readily demonstrated,—indeed it was here that it was first observed—there has been considerable doubt as to the extent to which the cells of the *Fucoideæ* are thus connected. As examples of the latter group Kohl studied *Himanthalea lorea* and several species of *Fucus*. He states that by the use of the method just described he has been able to demonstrate a general continuity of protoplasm between the various cells of these plants; and that the phenomenon is by no means confined, as some have supposed, to the so-called sieve-hyphæ.

B. L. R.

III. Miscellaneous Scientific Intelligence.

1. *The Journal of Comparative Neurology.* A Quarterly Periodical devoted to the Comparative Study of the Nervous System. Edited by C. L. Herrick, Professor Biol. Univ. Cincinnati. 106 and xviii pages, 8vo. Cincinnati, Ohio.—This first

number of this new quarterly shows capacity in the editor to do well his part in conducting it. The first two papers, covering 35 pages, are by Prof. Herrick: the first, "Contributions to the comparative morphology of the central nervous system," with plates I–IV, and the second, "Topography and histology of the brain of certain reptiles, with plates IX–X. Another article, over 50 pages in length, by C. L. Twines, treats of the morphology of the Avian brain, and is illustrated by plates V to VIII. In addition there are many notes from other journals, and a list of new publications, besides a statement by the editor of "the problems of comparative neurology," setting forth the range of especially important subjects, which it is the object of the journal to elucidate. On account of the high character of the journal and the great importance of the field it covers, it deserves liberal support.

2. *A Journal of American Ethnology and Archæology.* Editor, J. Walter Fewkes. Vol. I, 132 pp. Boston and New York, 1891 (Houghton, Mifflin & Co.).—The first volume of this new journal gives gratifying promise as to the interest and value of the series which it commences. The leading article by the editor, Mr. Fewkes, is upon some summer ceremonials at Zuñi Pueblo, giving results obtained in connection with the Hemenway Southwestern Archæological Expedition. It is liberally illustrated, and gives a very interesting account of some of the dances and other ceremonies of this curious people. A second paper is on Zuñi melodies by Benjamin Ives Gilman, accompanied by musical scores. A third paper, also by the editor, is on a reconnoisance of ruins in or near the Zuñi reservation, with maps and other illustrations. The publishers have made the appearance of the volume very attractive. (Price two dollars).

3. *Helmholtz Celebration and Medal.*—Steps are being taken to celebrate the seventieth birthday of Professor von Helmholtz, which occurs on August 31st. A marble bust of Professor Helmholtz is being made which will be presented to him on that occasion, and a fund is being raised the income of which is to be applied, primarily, to the bestowal of a *Helmholtz medal* on eminent investigators of all nations in the fields of Professor Helmholtz's activity. An international committee, which has been formed to carry out these schemes, solicits contributions, which may be sent to the committee's bankers, Mendelssohn & Co., Berlin. Professor Henry P. Bowditch of Harvard University will forward the contributions of such as may find it more convenient to send to him, with the names of the contributors, to the bankers appointed by the committee. We understand also that an especial movement has been started among ophthalmologists and otologists of this country and Canada, whose contributions are received and forwarded by Dr. Herman Knapp of New York. All contributions should be sent as soon as possible.

4. *National Academy of Sciences.*—The following is a list of papers accepted for reading at the meeting held at Washington, April 21–24:

A. S. Packard: Further studies on the brain of Limulus Polyphemus.
S. P. Langley: On aerodromics.
F. H. Bigelow: The Solar Corona, an instance of the Newtonian potential in the case of repulsion.
J. S. Billings: Report on the human bones of the Hemingway collection in the U. S. Army Medical Museum, prepared by Dr. Washington Matthews, U. S. A.
A. A. Michelson: Application of interference methods to spectroscopic measurements.
H. S. Pritchett: The Corona from photographs of the eclipse of Jan. 1, 1889.
Lewis Boss: Stellar motion problems.
Ira Remsen: Effect of pressure and temperature on the decomposition of diazo-compounds. Researches on the double halides.
M. Carey Lea: Allotropic silver; note on a paper by M. G. Lippmann.
H. A. Rowland: On the yttrium earths, and a method of making pure yttrium.
E. D. Cope: On the distribution of colors in certain North American reptiles.
Theo. Gill: The taxonomy of the apodal fishes.
W. K Brooks and E. G. Conklin: Researches on the embryology of mollusks.
Report of the Watson Trustees, and Presentation of the Watson Medal to Prof. Arthur Auwers of Berlin.

5. *Magnetite Ore Districts of Brazil—Erratum.*—Dr. O. A. Derby informs the Editors that the mineral occurring with the magnetite at Ipanema and referred to on page 316 of the April number as enstatite, has proved on further examination of better material to be barite. One specimen shows free crystals of barite upon its surface.

Examen Quimico y Bacteriologico de las Aguas Potables por A. E. Salazar y C. Newman; con un capitulo del Dr. Rafael Blanchard. 513 pp. 8vo, with seven plates. London, 1890.

Leçons sur les Métaux, Professées a la Faculté des Sciences de Paris, par Alfred Ditte, Professeur de Chimie à la Faculté. Premier Fascicule, Paris, 1891.

The number system of Algebra treated theoretically and historically by Henry B. Fine, Ph.D. 131 pp. 12mo. Boston and New York, 1891.

Report of the Superintendent of the U. S. Coast and Geodetic Survey for the year ending June, 1888, pp. 566. 4to, Washington, 1889.

Determinations of Latitude and Gravity for the Hawaiian Government, by E. D. Preston, pp. 563. 4to, Washington, 1890. (United States Coast and Geodetic Survey, Appendix 14.)

The International Astrophotographic Congress and a Visit to Certain European Observations and other Institutions, by Albert G. Winterhalter, pp. 354. 4to, Washington, 1889. (Washington Observations, 1885, Appendix I.)

Magnetic Observations at the United States Naval Observatory, 1888 and 1889, by Ensign J. A. Hoogewerff, U. S. Navy, pp. 100. 4to, Washington, 1890, (Washington Observations, 1886, Appendix I.)

Saturn and its Ring, 1875–1889, by Asaph Hall, Prof. of Mathematics, U. S. Navy, pp. 22. 4to, Washington, 1889. (Washington Observations, 1885, Appendix II.)

Brachiopoden der Alpinen Trias von A. Bittner, pp. 325. 4to, Wien, 1890. (Alfred Hölder, Vienna Academy.)

OBITUARY.

Joseph Leidy.—Dr. Joseph Leidy, the eminent Comparative Anatomist, Zoologist and Paleontologist, died at Philadelphia on the 30th of April. He was born in the same city on the 9th of September, 1823. His father was a native of Montgomery County, Pa., but his ancestors on both sides were Germans from the valley of the Rhine. While yet a school-boy, minerals and plants were eagerly collected and studied, and also anatomical dissections were begun, a barnyard fowl being the first subject. He entered the Medical School of the University of Pennsylvania in 1840 and devoted his first year to practical anatomy. Having taken his medical degree in 1844, he became the next year, then 21 years of age, Prosector to Dr. Horner, Professor of Anatomy in the university; and at the death of Dr. Horner, in 1853, he was appointed his successor.

In 1844 he made the many remarkable dissections of terrestrial mollusks, the drawings of which cover sixteen plates and illustrate thirty-eight species in Dr. Binney's fine work on the Terrestrial Mollusks of the United States—showing in all not only remarkable power as an anatomist entitling him to high rank, as Dr. Binney remarks, among philosophical zoologists, but also great skill as a draftsman. Thus, from the first, Dr. Leidy was the thorough, minutely accurate and untiring investigator.

After the publication of Dr. Binney's work in 1845, he was elected a member of the Academy of Natural Sciences of Philadelphia; and from that time he was its most active member, hardly a volume of its publications appearing without one or more papers on the results of his researches.

Dr. Leidy's contributions to Zoology and Comparative Anatomy have a wide range. The Lower Invertebrates occupied a large share of his time. Besides multitudes of short papers, he published in 1853, a work of 67 pages, illustrated by ten plates, on "A Flora and Fauna within Living Animals"—of the botanical part of which Dr. Gray said in this Journal—"a contribution of the highest order, the plates unsurpassed if not unequalled by anything before published in the country." In 1879 appeared his large quarto volume on the fresh-water Rhizopods of North America, containing 48 colored plates, the material of which was in part collected during two seasons in the Rocky Mountain region under the auspices of the Hayden Exploring Expedition. As a portraiture of the Doctor over the little memberless species, we quote from his concluding remarks: "The objects of my work have appeared to me so beautiful, as represented in the illustrations, and so interesting as indicated in their history which forms the accompanying text, that I am led to hope the work may be an incentive, especially to my young countrymen to enter into similar pursuits. 'Going fishing?' How often the question has been asked by acquaintances as they have met me, with rod and basket, on an excursion after mate-

rials for microscopic study. 'Yes,' has been the invariable answer, for it saved much detention and explanation; and, now, behold, I offer them the result of that fishing. No fish for the stomach, but as the old French microscopist, Joblet, observed, 'some of the most remarkable fishes that have been seen,' and food fishes for the intellect." He delighted in his work because he knew that there was no fact in connection with the structure and functions of the simplest of living things that was not profound and comprehensive, that did not reach up through all species to the highest.

The Vertebrates described by him were mainly fossil species. Dr. Leidy has the honor of having opened to geological science a general knowledge of the remarkable mammalian fauna of the country, and especially that of the Rocky Mountain region. Species had been before described, but through him the general range of North American species began to be known. In 1847, he published on the fossil Horse; in 1850, on the extinct species of the American Ox; in 1852, and 1854 on the extinct Mammalia and Chelonia from Nebraska Territory, collected during the survey under Dr. D. D. Owen; in 1855, on the extinct Sloth tribe of North America; in 1869, on the extinct Mammalian fauna of Dakota and Nebraska, a thick quarto volume published by the Philadelphia Academy of Sciences, based on materials that had been gradually and continuously accumulating for the last twenty years; and in 1873 contributions to the extinct Fauna of the Western Territories, making the first quarto volume of the Hayden Survey. The last two works mentioned contain over 800 pages of text and nearly 70 of plates. Besides these large works numerous short papers from time to time appeared.

Dr. Leidy retired from this particular field when questions of priority began to start up, it being no part of his nature to quarrel, and having the firm belief, as he said, that the future would award credit where it was deserved. His work among the fossil Vertebrates extended also to Fishes, Batrachians and Reptiles of different geological periods, and among his contributions, that on the Reptiles of the Cretaceous period of 1865, published by the Smithsonian Institution, covers 136 pages and is illustrated by 20 plates.

Dr. Leidy's zeal never flagged; his labors came to an end only with his sudden death. Eight days before, he delivered his last University lecture. Beginning original work before he was twenty, his published papers and larger books continued to appear through half a century and number over nine hundred. As is well said in one of the many tributes to him published in the Philadelphia papers after his decease:

"He possessed to the end of a long career the freshest capacity of seeing the opportunities and openings for discovery and research offered by familiar phenomena. His vast store of exact and diverse knowledge in the whole wide field of animate nature was under the command of a logical judgment and synthetic

powers which saved him from vagaries. These high intellectual powers were served by an untiring capacity for work and equal skill of eye and hand.

"These are rare gifts; but they are none of them, nor all of them put together, as rare as his character. His simplicity, his transparent sincerity, his ingenuous anxiety to serve science and to serve science alone, his freedom from all desire for the rewards, the honors and the recognition after which lesser men go a-wandering, were as remarkable as his scientific powers."

Never were words more truthful. Honors came to him from all parts of the civilized world, and more because unsought.

Dr. Leidy leaves a wife and an adopted daughter.

JOHN LECONTE, Professor of Physics and Industrial Mechanics in the State University at Berkeley, California, died on the 29th of April, aged 72 years. Professor LeConte, the oldest son of the naturalist, Lewis LeConte, was born in 1818 in Liberty County, Georgia. He was graduated from Franklin College, now the University of Athens, Georgia, when he was twenty years old, and from the College of Physicians and Surgeons in New York City three years later. He then entered upon the practice of medicine at Savannah where he remained for four years. In 1846 he was called to the Chair of Natural Philosophy in Franklin College, which he occupied until 1855. In the following year he lectured on chemistry at the College of Physicians and Surgeons in New York City; in the same year he was made Professor of Natural and Mechanical Philosophy in South Carolina College at Columbia, S. C., a position which he held for thirteen years.

In 1869 he was appointed Professor of Physics and Industrial Mechanics in the University of California, and this position he retained until 1881. From 1876 to 1881 he held, in connection with his professorship, the office of President of the university, and at the expiration of that term he retired to the Chair of Physics, which he occupied until the time of his death.

Professor LeConte's energies were early devoted to medicine but later he turned toward physical science and in both departments he made numerous contributions which have been published in the Proceedings of the American Association and in various scientific journals. Among those which have appeared in this Journal may be mentioned papers on the influence of musical sounds on gas jets; on the influence of solar light upon combustion; physical studies on the waters of Lake Tahoe; several papers upon various aspects of the phenomena of capillarity; also on sound shadows in water. In 1857 he delivered a course of lectures on "The Physics of Meteorology" before the Smithsonian Institution, in Washington, and in 1867 he read an important paper on "The Stellar Universe" before the Peabody Institute, in Baltimore. His whole list of published writings includes about a hundred papers extending over a wide range of subjects.

In 1879 he received the degree of LL.D. from the University of Georgia and the same year he was made a member of the National Academy of Sciences. A younger brother, Professor Joseph LeConte, also of the University of California, and closely associated with him through life, is well known as a geologist and physiologist.

JULIUS ERASMUS HILGARD, late Superintendent of the United States Coast Survey, died at his home in Washington on the 8th of May, after a long and painful illness. He was the son of Theodore Erasmus Hilgard, an eminent German jurist, and was born in Zweibrücken, Bavaria, Jan. 7, 1825. He came to this country when ten years of age, and until 1843 resided in Belleville, Ill. In that year he removed to Philadelphia, where he took up the study of civil engineering, and two years later he became one of the assistants of Professor Bache on the Coast Survey. In 1862 he was promoted to the position of assistant in charge of the Coast Survey Office. This position he held until 1881, when, upon the death of Captain Patterson, he was appointed Superintendent; increasing physical disability, however, interfered with the discharge of his duties and finally led to his resignation, which took effect in 1886.

Dr. Hilgard's active labors, for nearly forty years, were chiefly in connection with the development and administrative work of the Survey, and here he did very important and valuable service to science and to the country. He had charge of the construction and verification of the standards of weights and measures, and was for some time engaged in preparing metric standards for distribution to the several States. He was also engaged in researches and the discussion of the results in geodesy and in terrestrial physics and in perfecting methods and instrumental means connected with them. One of the most important pieces of work with which he was connected was the determination of transatlantic longitude in 1872; a result of this was to establish an important correction to the longitude of Paris as reckoned from Greenwich. A chart compiled by him giving the magnetic declination over the United States for 1875 was issued in connection with the Coast Survey Report, and, also with a descriptive article in this Journal (xix, 173).

Professor Hilgard was one of the original members of the National Academy of Sciences, and served for years as its Home Secretary. He was made President of the American Association for the Advancement of Science in 1874.

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* This Index contains the general heads BOTANY, CHEMISTRY, GEOLOGY, MINERALS, OBITUARY, ROCKS, and under each the titles of Articles referring thereto are mentioned.

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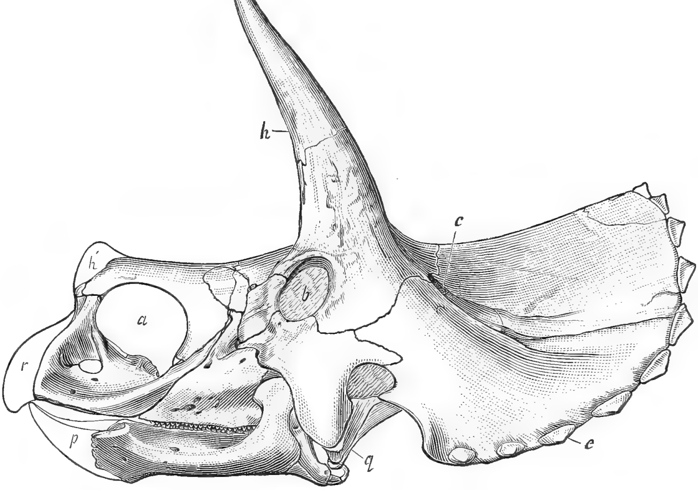

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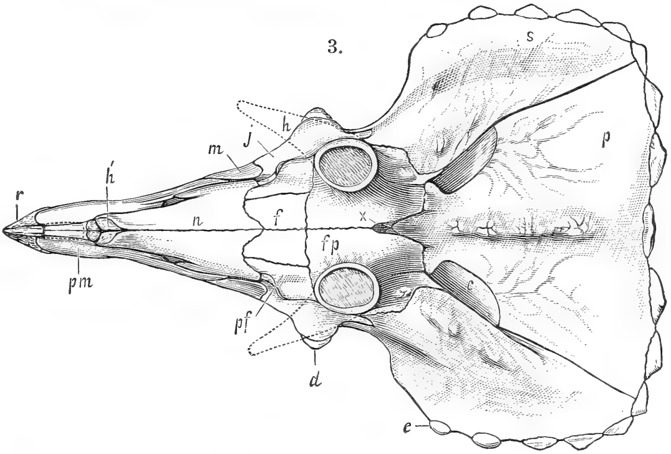

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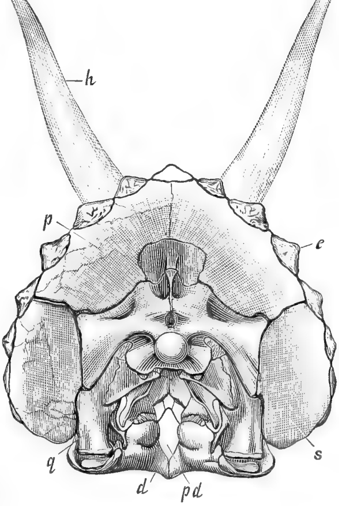

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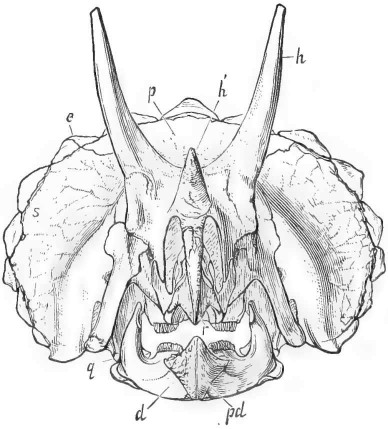

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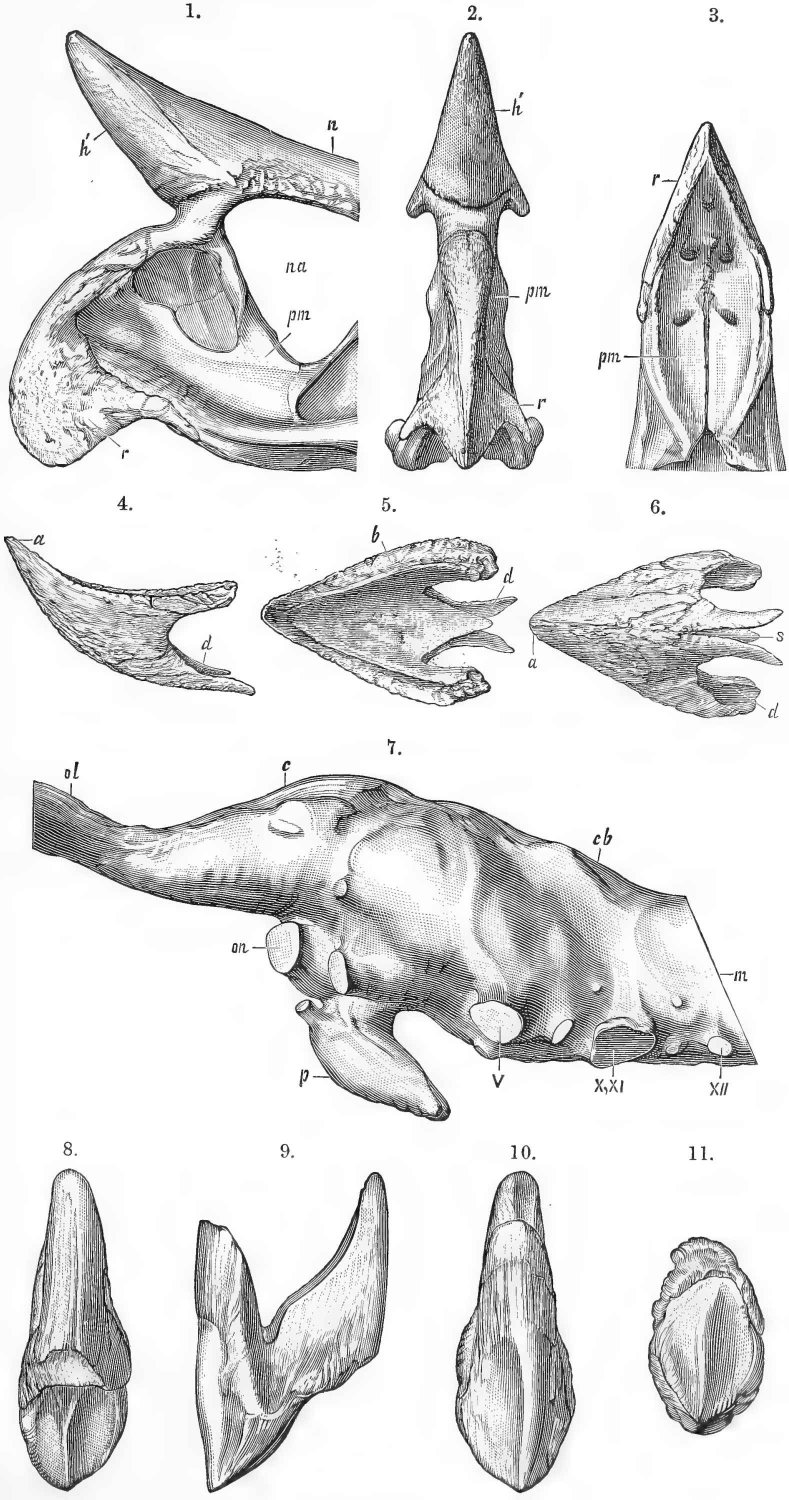
C.D. WALCOTT.



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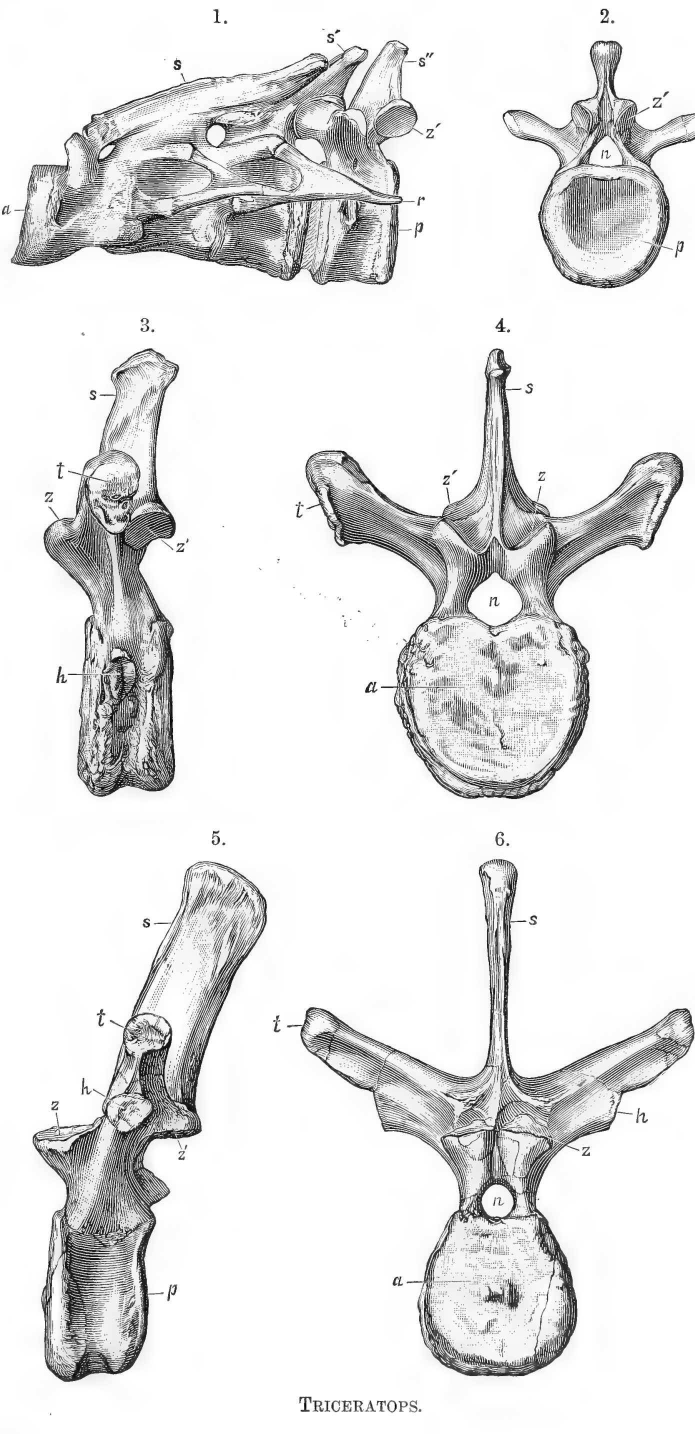

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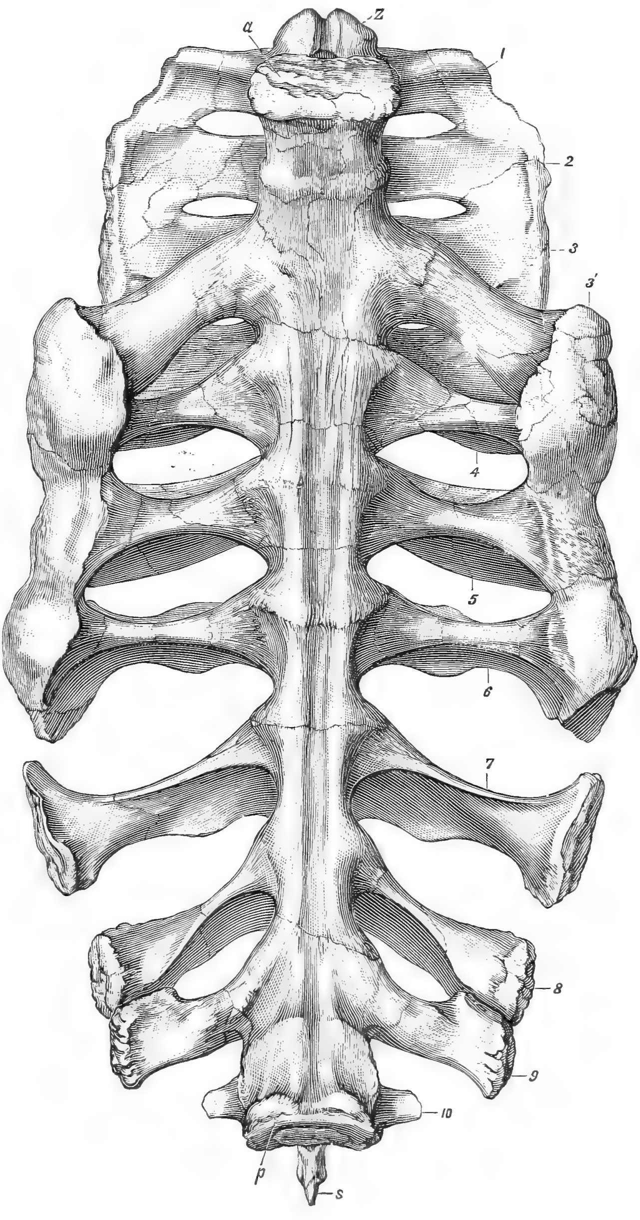

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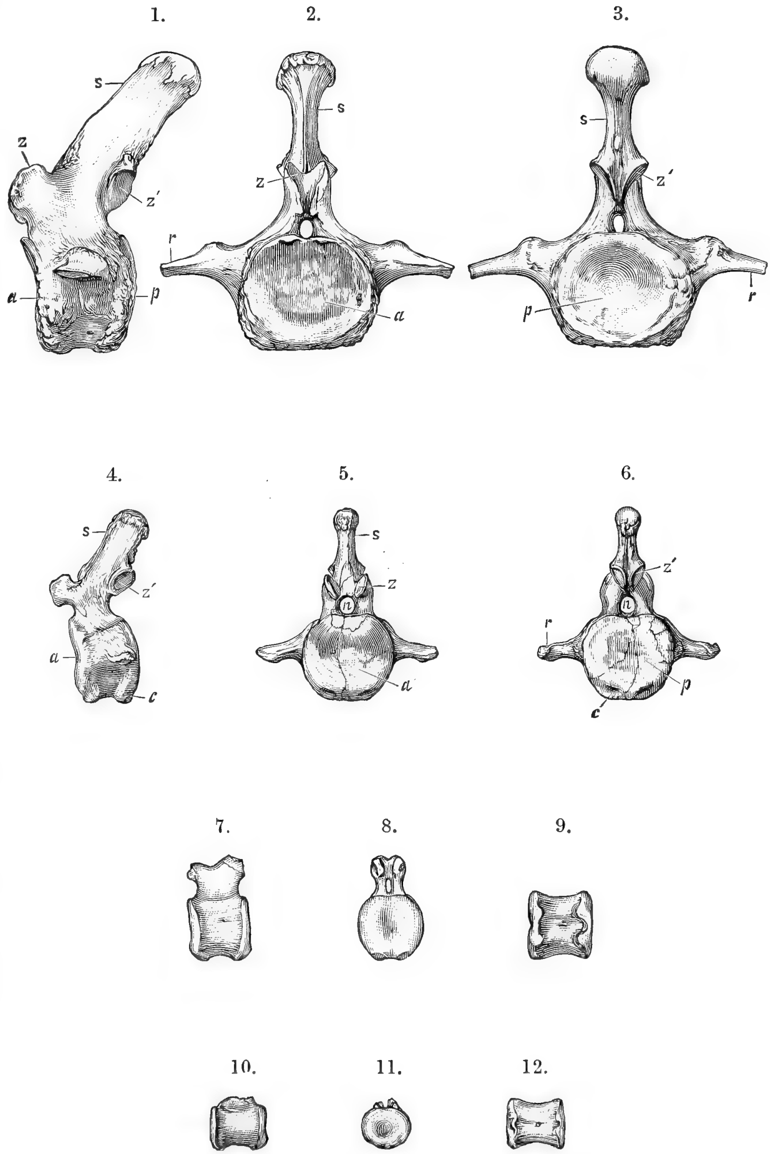

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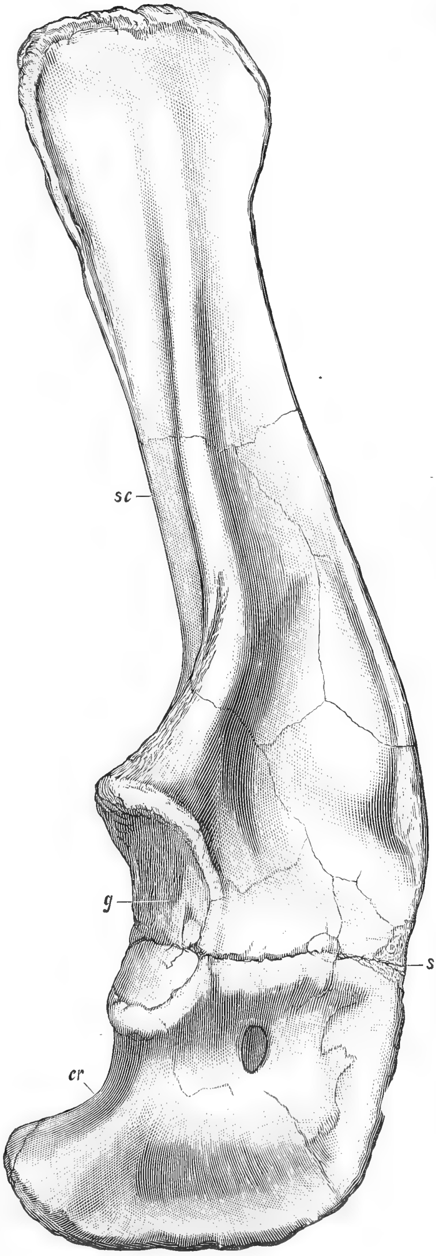

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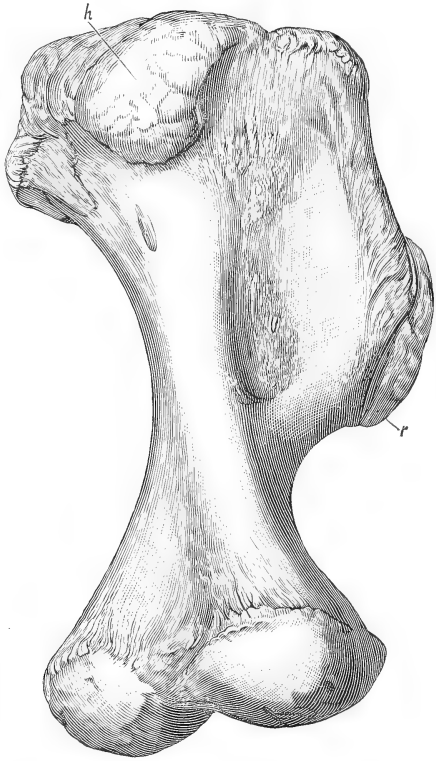

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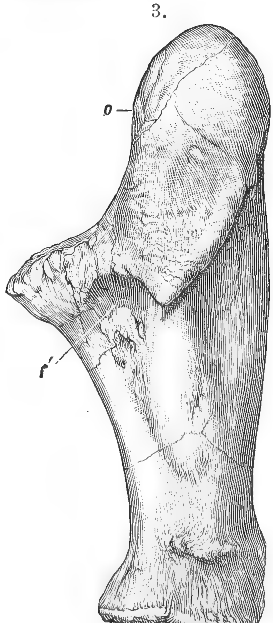

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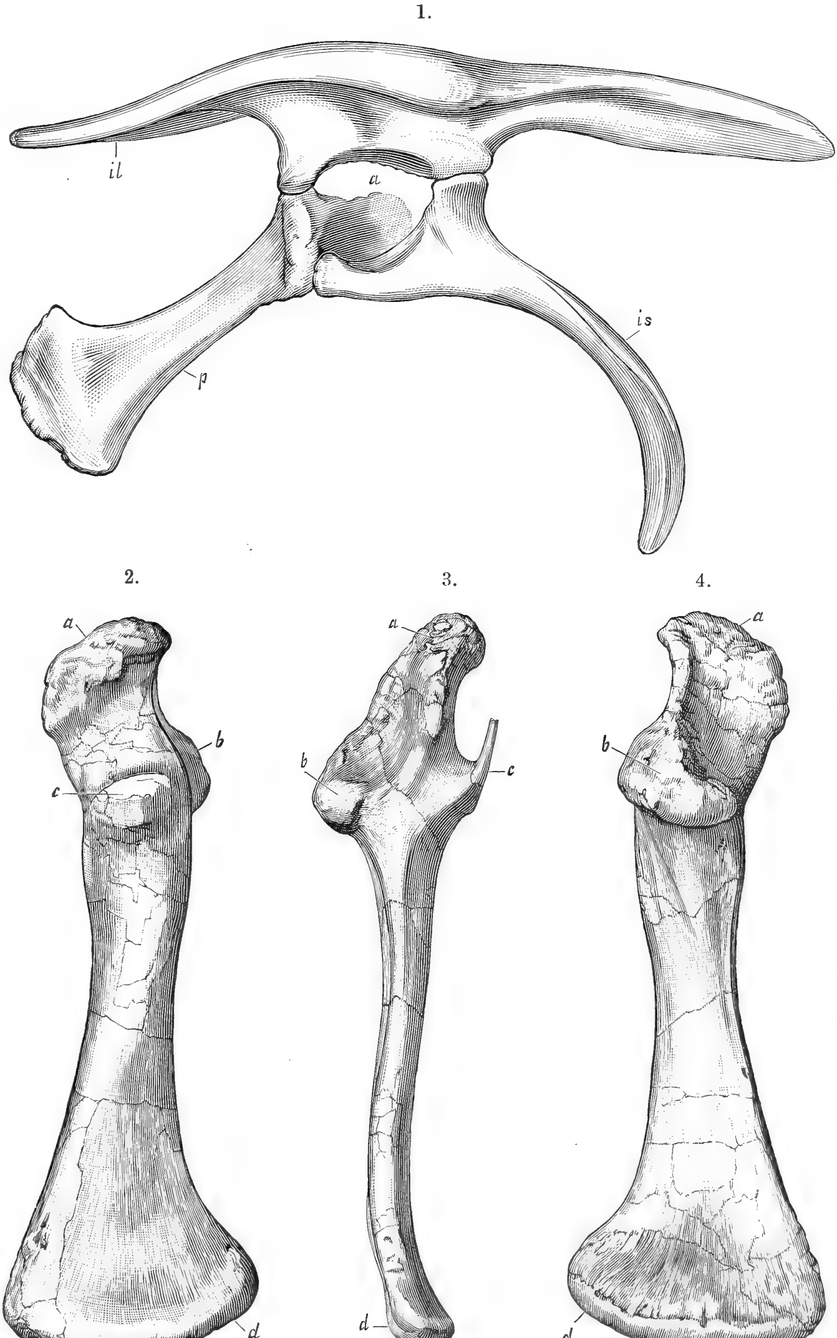

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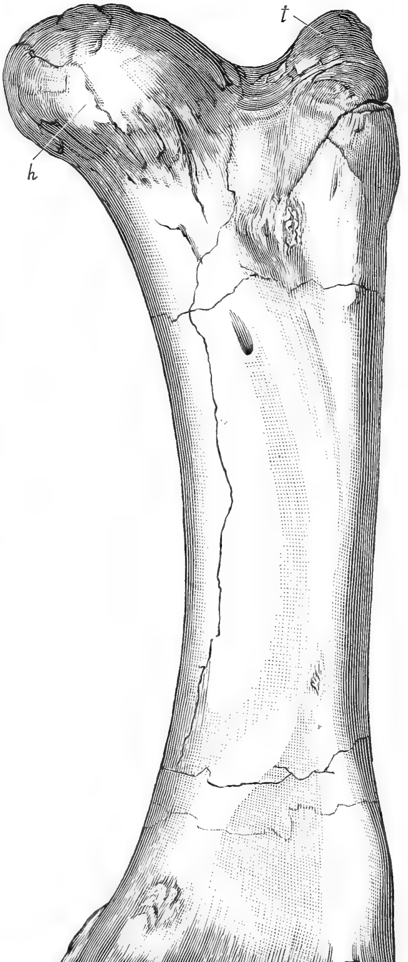

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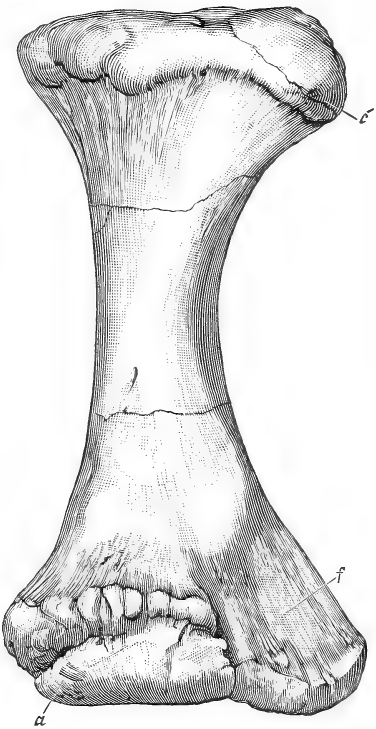

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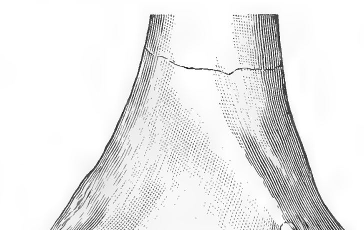

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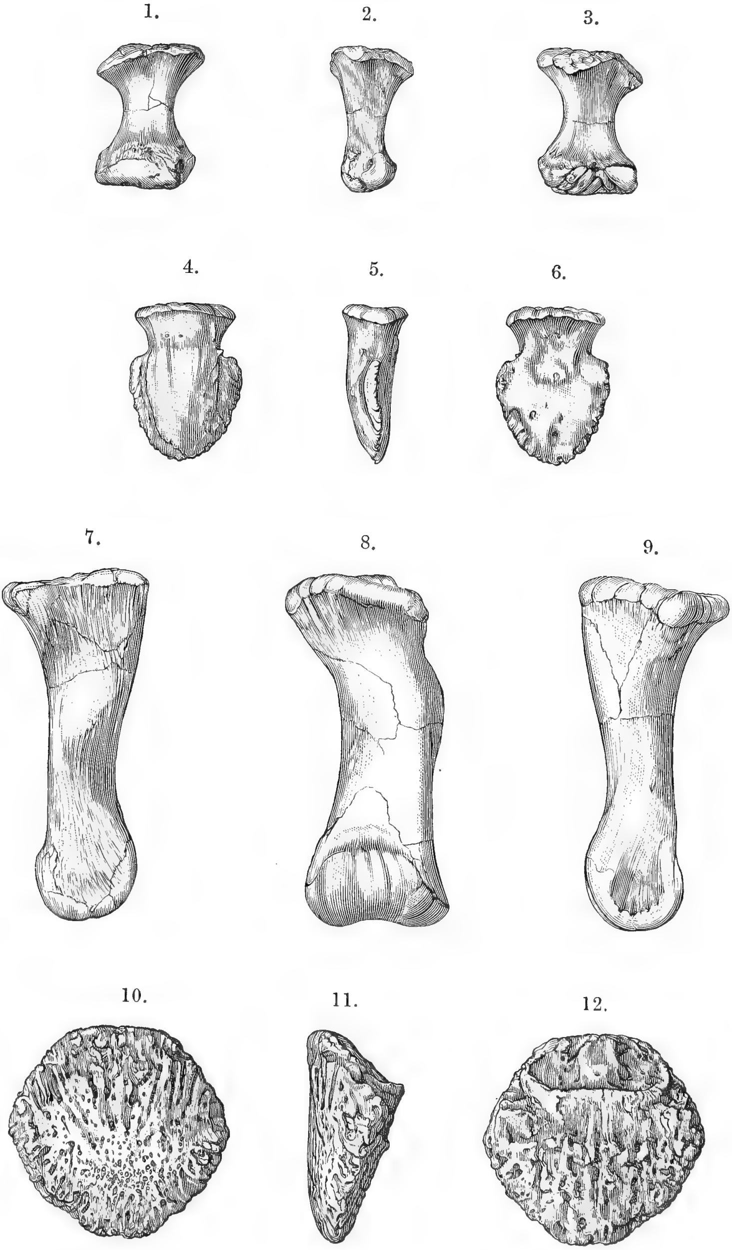

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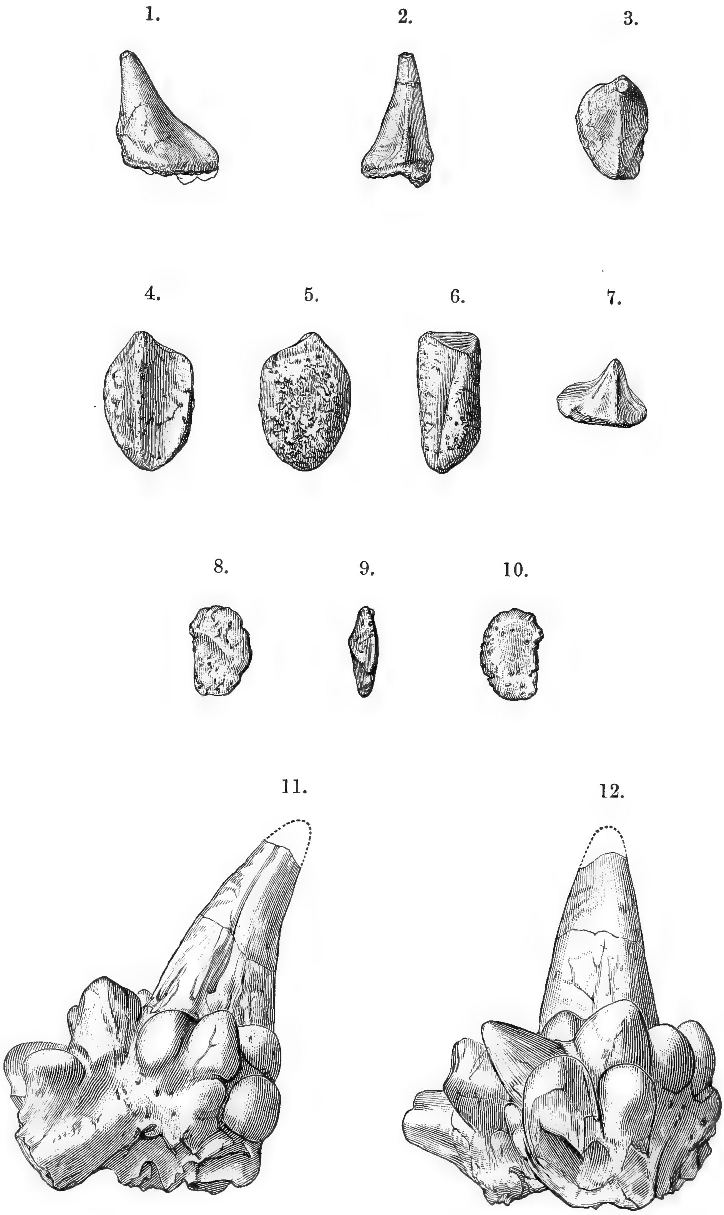

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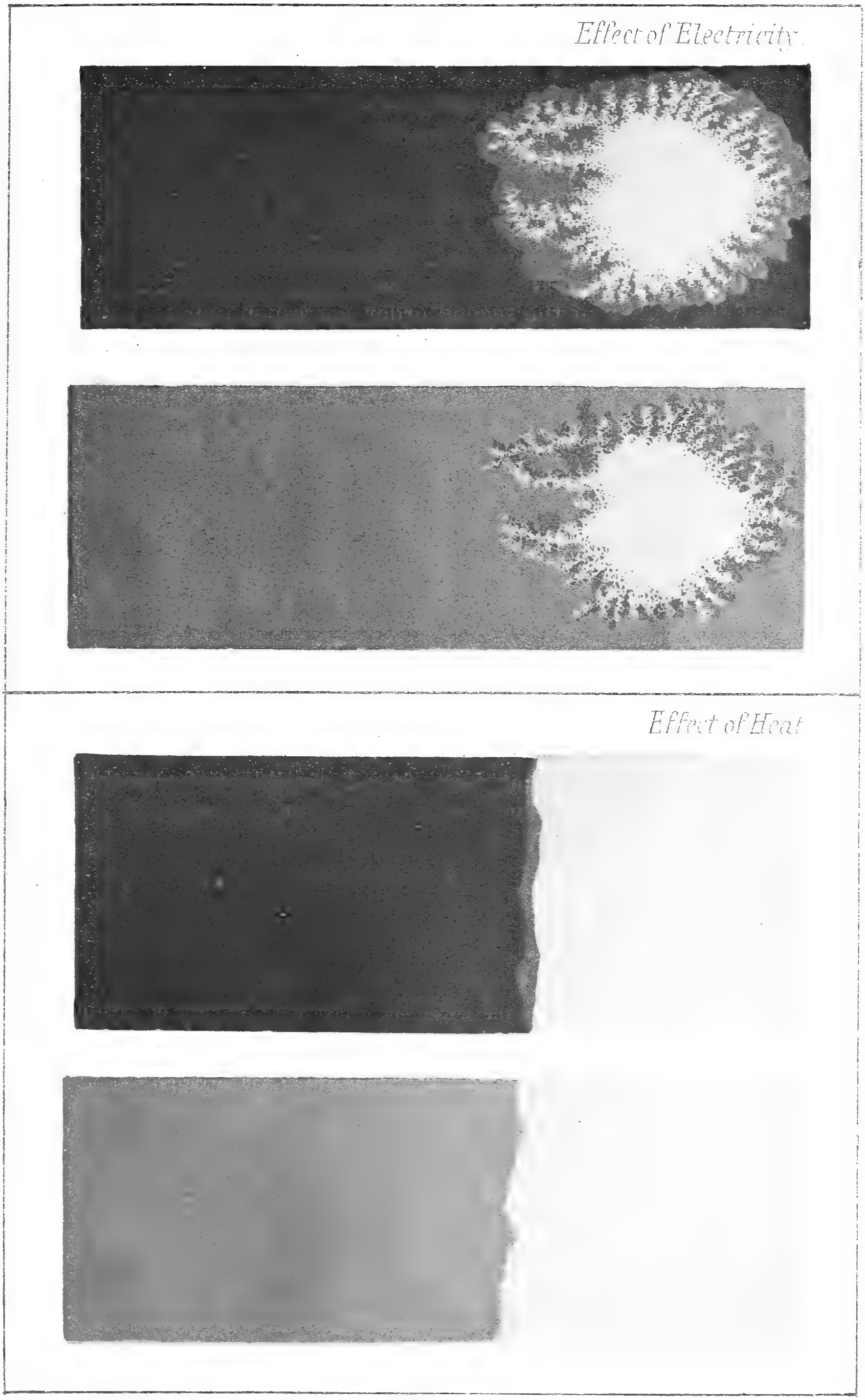

ALLOTROPIC SILVER.

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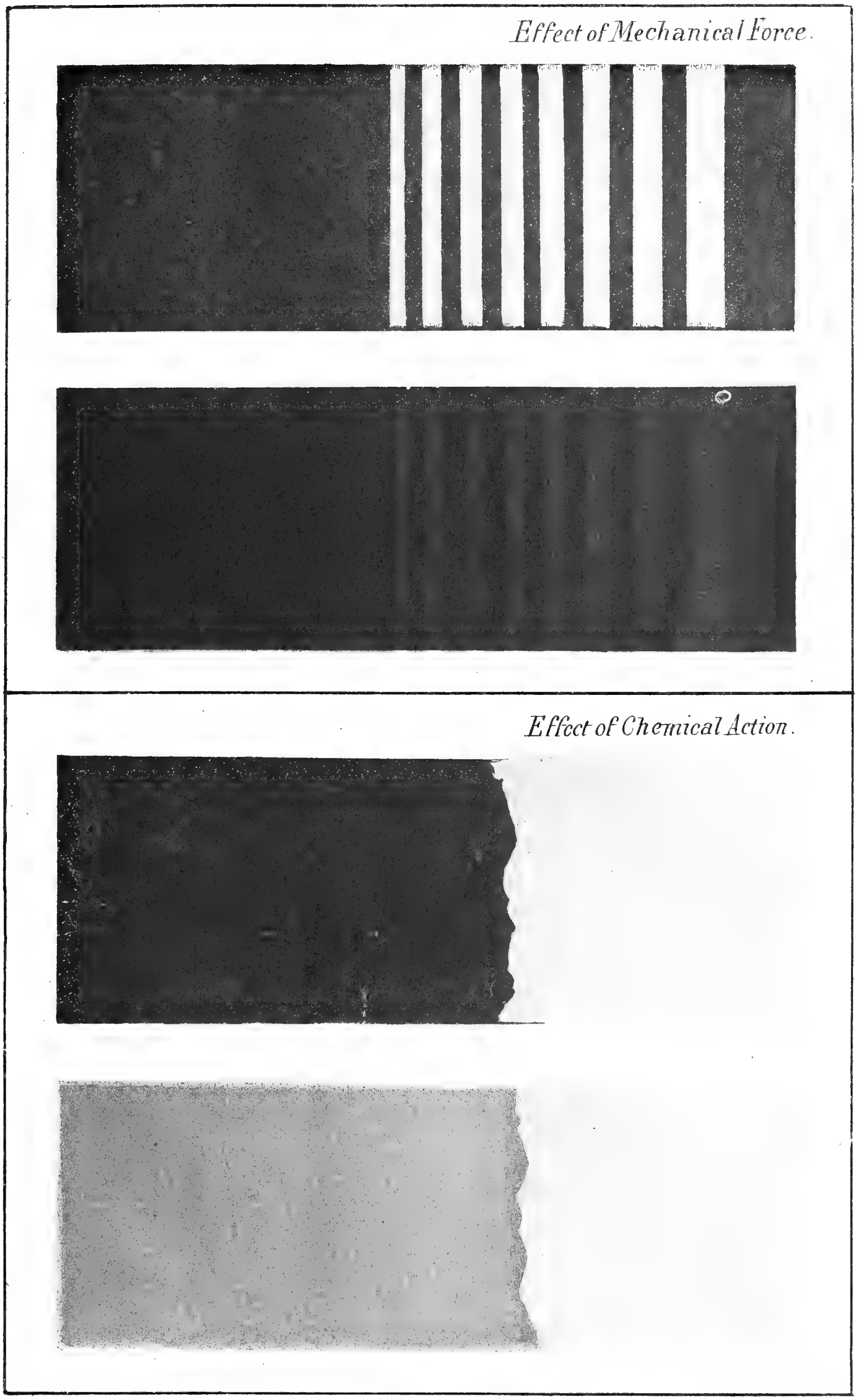
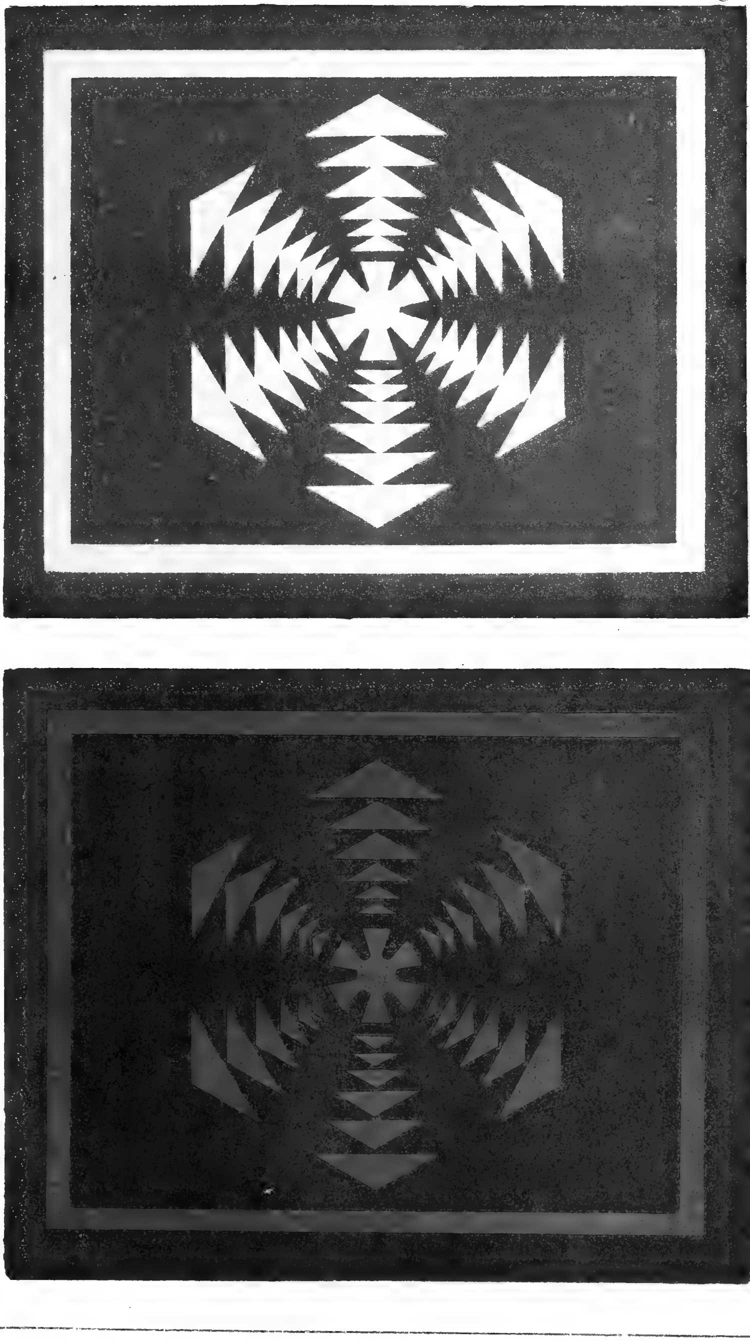
PLATE II



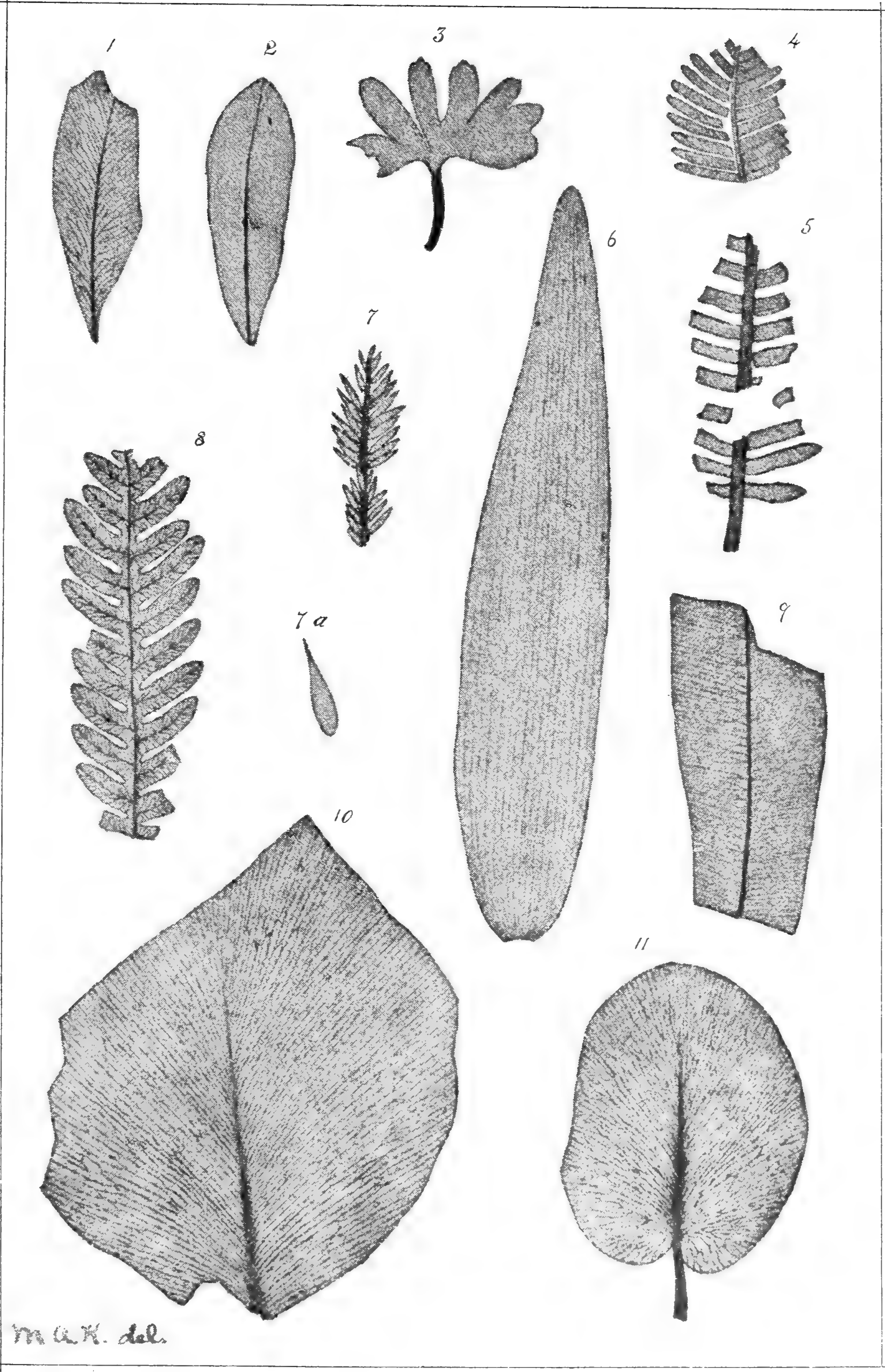
ALLOTROPIC SILVER.

PLATE III.

Effect of Light



ALLOTROPIC SILVER.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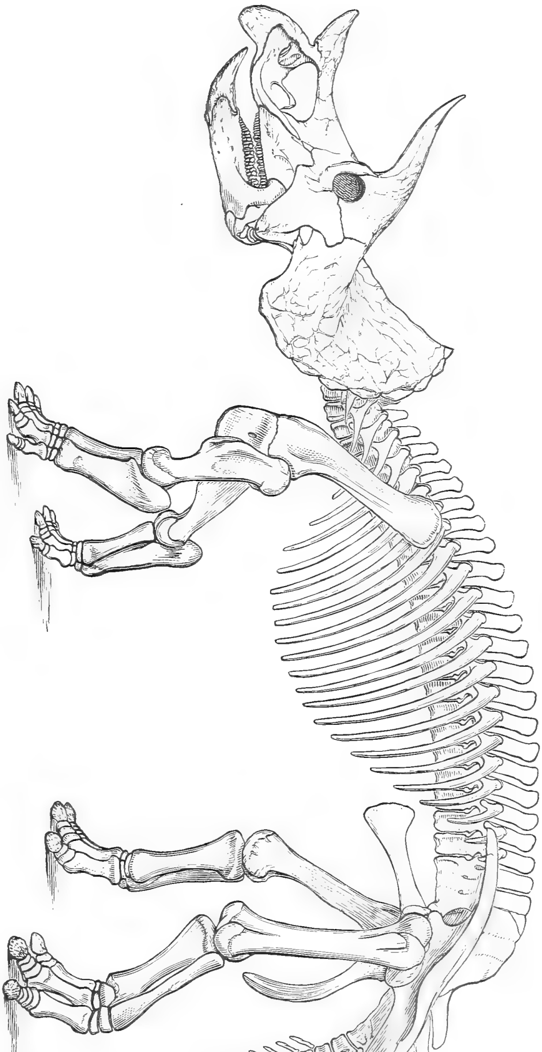
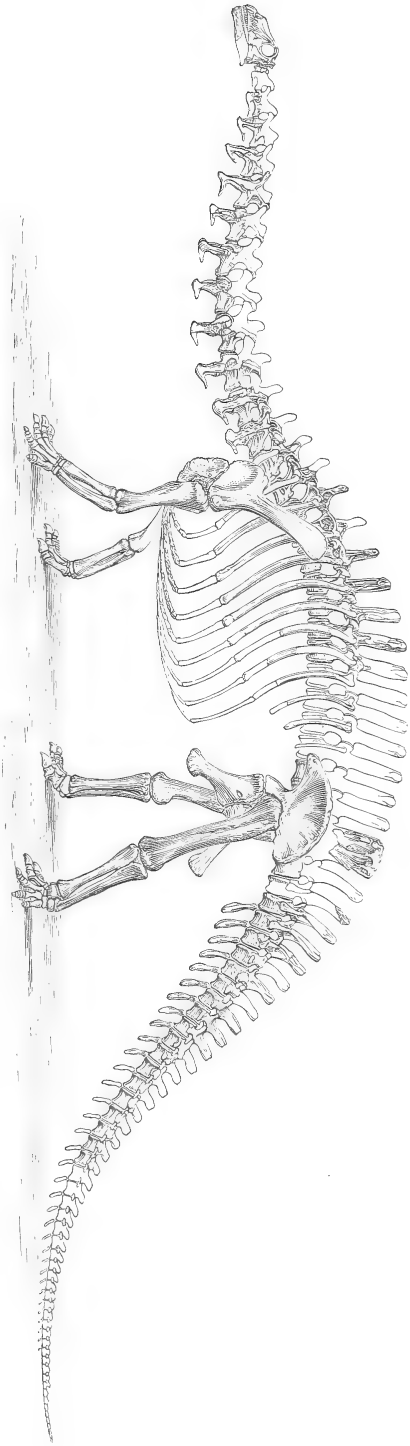
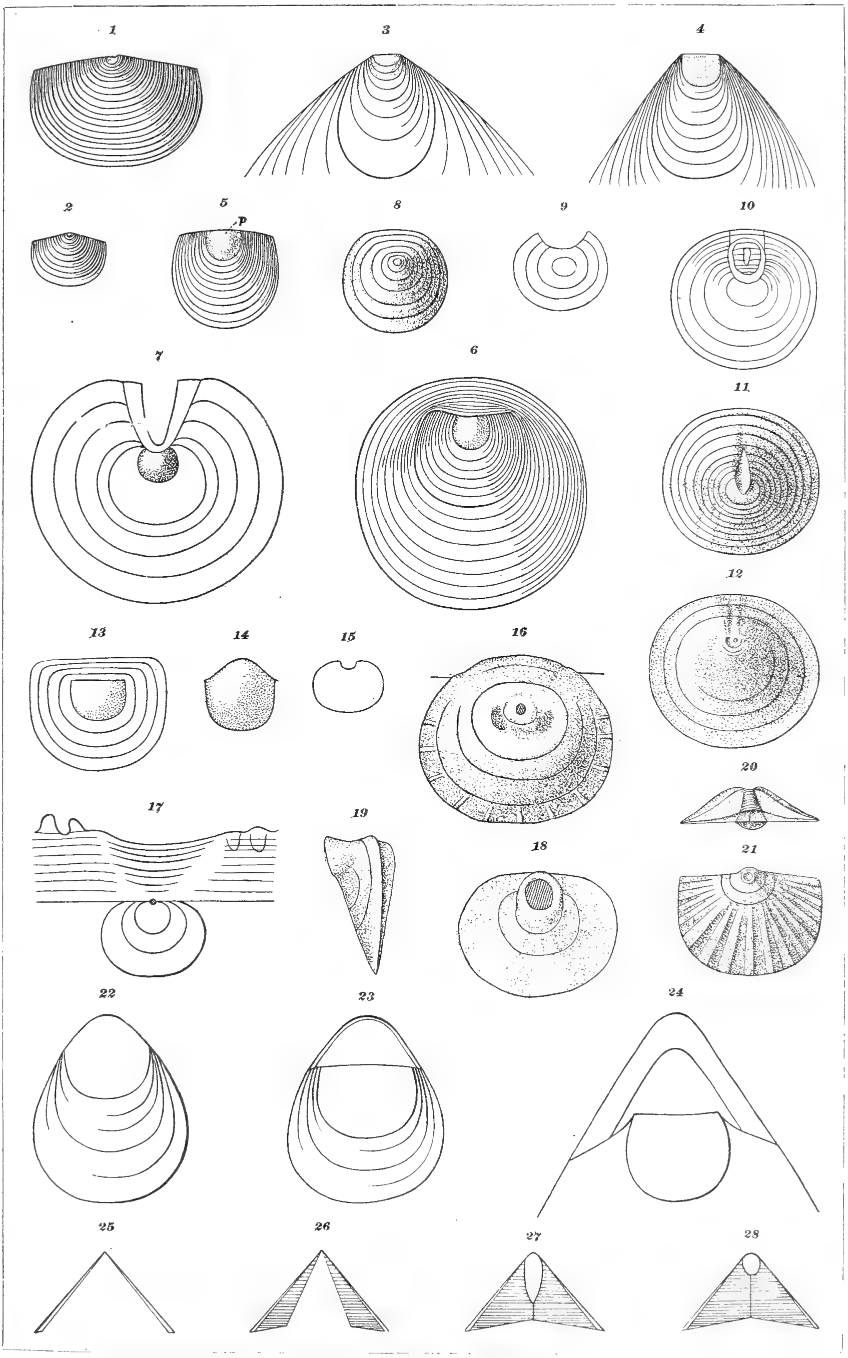


Restoration of TRICERATOPS PRORSUS, Marsh. One-fortieth natural size.



Restoration of BRONTOSAURUS EXCELSUS, Marsh. One-ninetieth natural size.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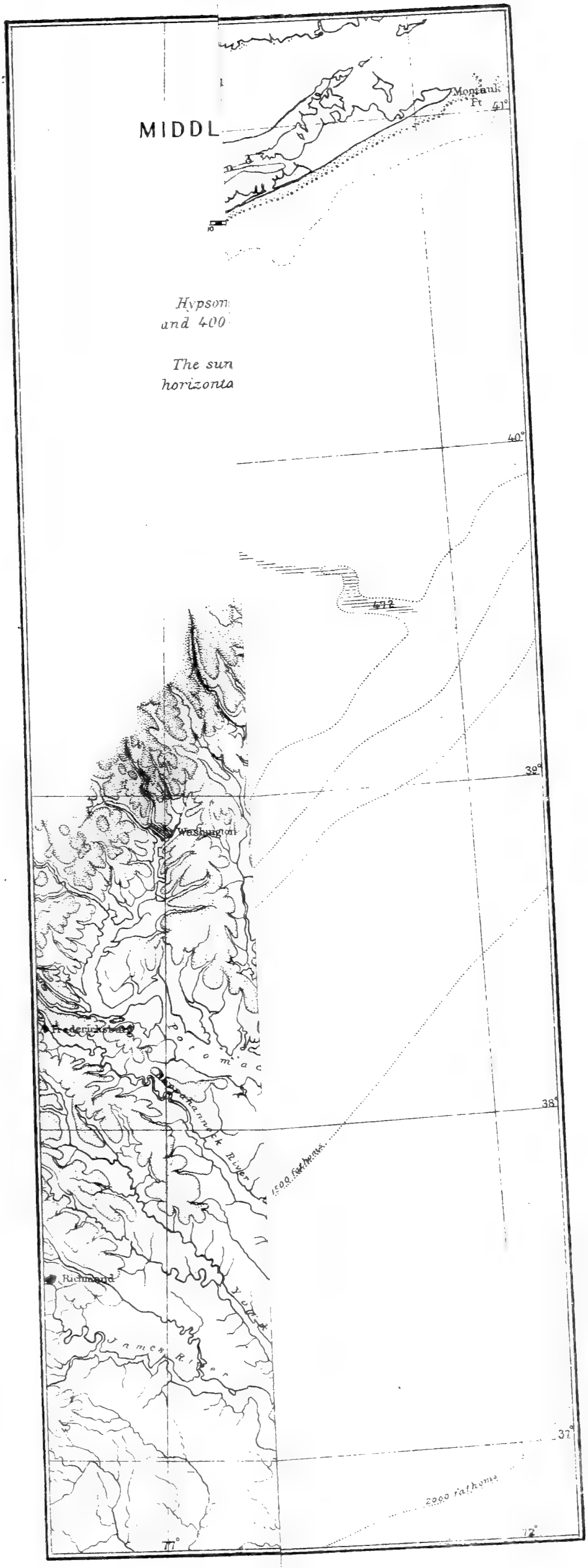
MIDDL
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horizonta
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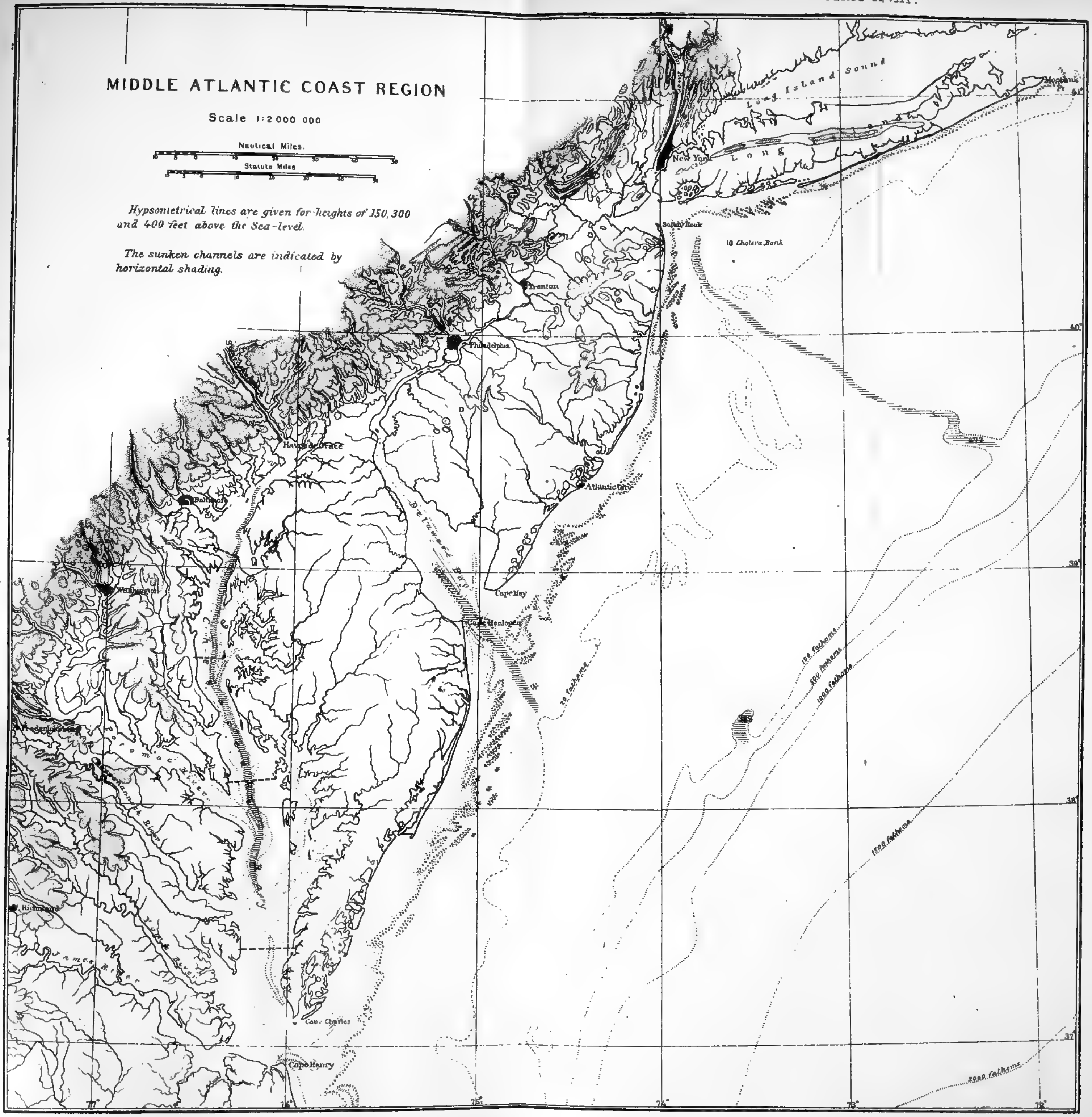
Potomac
Rappahannock River
York
Richmond
James River
1500 fathoms
2000 fathoms
71°
72°


MIDDLE ATLANTIC COAST REGION
Scale 1:2 000 000
Nautical Miles.
Statute Miles
Hypsometrical lines are given for heights of 150, 300 and 400 feet above the Sea-level.
The sunken channels are indicated by horizontal shading.
Long Island Sound
Long Island
New York
Montauk Pt.
Sandy Hook
10 Cholera Bank
Trenton
Philadelphia
Havre de Grace
Baltimore
Washington
Atlantic City
Delaware Bay
Cape May
Cape Henlopen
Potomac River
Richmond
James River
Cape Charles
Cape Henry
20 fathoms
100 fathoms
500 fathoms
1000 fathoms
1500 fathoms
2000 fathoms
41°
40°
39°
38°
37°
77°
76°
75°
74°
73°
72°

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